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Revision 1, Draft A

Remedial Design/ Remedial Action Work Plan for the 100-NR-2 Operable Unit

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY

Richland Operations Office

P.O. Box 550
Richland, Washington 99352

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Signature Date

Washington State Department of Ecology

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Signature Date

Executive Summary

This revised remedial design/remedial action work plan (RD/RAWP), Rev. 1, sets forth the approach for implementing the activities necessary to install and maintain an apatite permeable reactive barrier (PRB) for the 100-NR-2 Groundwater Operable Unit (OU), as specified in the *Amended Interim Remedial Action Record of Decision for the 100-NR-1/NR-2 Operable Units of the Hanford 100-N Area* (EPA, 2010), hereafter referred to as the Interim Action record of decision (ROD) Amendment.

The Interim Action ROD Amendment revises the selected interim remedial action (RA) for the strontium-90 remedy in the 100-NR-2 Groundwater OU located within the U.S. Department of Energy 100-N, Hanford Site, Benton County, Washington. The revised interim RA replaces the pump-and-treat system with an apatite PRB. This amended interim RA decision, based on information contained in the Administrative Record for the 100-NR-2 OU, is necessary to protect the public health and welfare or the environment from actual or threatened releases of strontium-90.

The selected remedy combines apatite sequestration,[1] monitored natural attenuation, and institutional controls with the goal of reducing strontium-90 flux to the Columbia River by 90 percent within five years of completing all apatite injections. The mass of apatite to be emplaced within the PRB footprint is designed to sequester strontium-90 entering the PRB over the next 300 years. Achievement of the 90 percent flux reduction goal, in combination with implementation of a final RA to be identified in the 100-N remedial investigation/feasibility study report and proposed plan scheduled for completion in 2012, will support attainment of the 8 pCi/L remedial action goal for strontium-90 in the hyporheic zone by 2016. Concurrent with or following completion of the apatite PRB injections, the former interim RA pump-and-treat system will be decommissioned.

This RD/RAWP (Rev. 1) is organized into the following eight chapters:

- Chapter 1 identifies the purpose for the RD/RAWP and describes the history and environmental setting of 100-N.
- Chapter 2 presents the basis for the selected remedy as described in the Interim Action ROD Amendment.

[1] Apatite sequestration is an exchange process where strontium-90 and other divalent ions substitute for calcium in the apatite crystal matrix.

- Chapter 3 provides a conceptual design for the individual remedy components.
- Chapter 4 describes the project management team, facility procurement, and construction and operational approaches to implement the interim RA.
- Chapter 5 summarizes the environmental management controls associated with waste management, health and safety, emergency response, and the quality assurance program.
- Chapter 6 discusses interim RA completion requirements.
- Chapter 7 provides an initial cost estimate for the 2012 through 2016 period and a planning level schedule for apatite PRB build-out activities.
- Chapter 8 includes a listing of references cited.

This RD/RAWP (Rev. 1) was prepared to fulfill the Tri-Party Agreement Milestone M-015-60.

Contents

Figures

Tables

Terms

ALARA	as low as reasonably achievable
AR	Administrative Record
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
CCP	*Comprehensive Conservation Plan*
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CHPRC	CH2M HILL Plateau Remediation Company
COC	contaminant of concern
DOE	U.S. Department of Energy
DOE-RL	DOE Richland Operations Office (also known as RL)
DOS	design optimization study
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERA	expedited response action
ERDF	Environmental Restoration Disposal Facility
ESD	explanation of significant difference
FS	feasibility study
FY	fiscal year
HCRP	Hanford Cultural Resource Program
HHE	human health and the environment
IC	institutional control
ITRD	Innovative Treatment and Remediation Demonstration
IX	ion exchange
LWDF	Liquid Waste Disposal Facility
MNA	monitored natural attenuation
MTCA	WAC 173-340, "Model Toxics Control Act—Cleanup"

NCP	"National Oil and Hazardous Substances Pollution Contingency Plan," referred to as the National Contingency Plan
NEPA	*National Environmental Policy Act of 1969*
O&M	operations and maintenance
OU	operable unit
PRB	permeable reactive barrier
QA	quality assurance
QRA	qualitative risk assessment
RA	remedial action
RAG	remedial action goal
RAO	remedial action objective
RCBRA	River Corridor Baseline Risk Assessment
RCRA	*Resource Conservation and Recovery Act of 1976*
RD	remedial design
RD/RAWP	remedial design/remedial action work plan
RDR	remedial design report
RI	remedial investigation
ROD	record of decision
SAP	sampling and analysis plan
TAG	Technical Advisory Group
TD	total depth
TPA	Tri-Party Agreement
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TSD	treatment, storage, and/or disposal
TTP	treatability test plan

1 Introduction

Groundwater beneath 100-N of the Hanford Site has been contaminated with radionuclides, metals, petroleum hydrocarbons, and ionic constituents from wastewater disposal practices and spills associated with 100-N Reactor operations. In accordance with the requirements of the *Hanford Federal Facility Agreement and Consent Order*, also known as the Tri-Party Agreement (TPA) (Ecology et al., 1989a), and the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) (as amended by the *Superfund Amendments and Reauthorization Act of 1986*), cleanup actions have been initiated at 100-N. 100-N is shown in Figure 1-1.

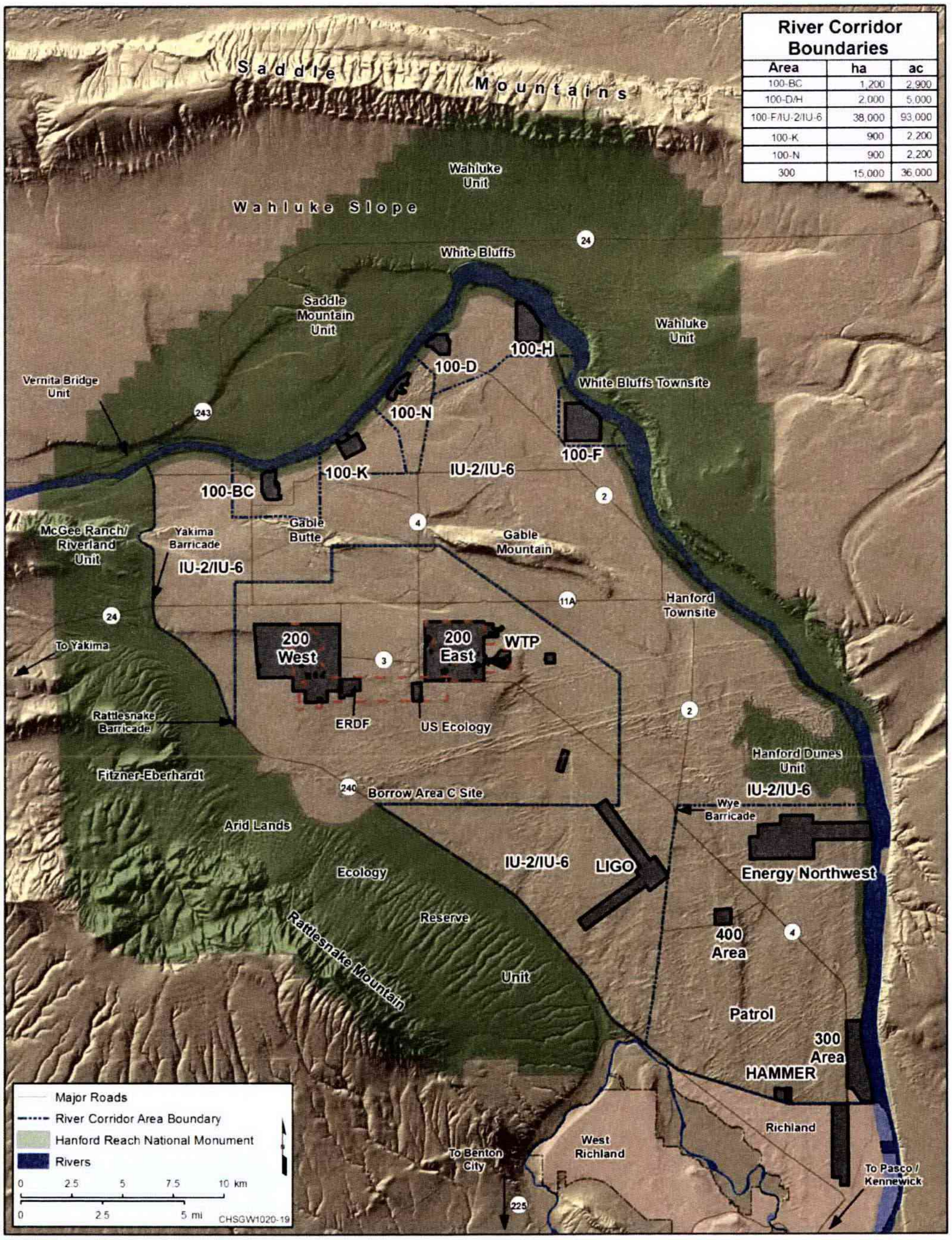

Figure 1-1. Hanford Site in Washington State and 100-N Location

100-N is divided into two operable units (OUs): 100-NR-1 and 100-NR-2. The 100-NR-1 OU includes four treatment, storage, and/or disposal (TSD) units regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA), 81 initially identified source waste sites, and a shoreline site. Since interim actions were implemented at 100-N, additional source waste sites have been identified. The groundwater beneath 100-N constitutes the 100-NR-2 OU. Of primary concern in the 100-NR-2 OU, is the presence of strontium-90 that enters the nearby Columbia River via natural groundwater upwelling through the river bottom. Historically, groundwater also entered the river through riverbank seeps identified as N-Springs. The site-related riverbank seeps, resulting from historic groundwater elevation mounding beneath 100-N, are no longer present.

On September 30, 1999, an *Interim Remedial Action Record of Decision (ROD) for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington* (EPA/ROD/R10-99/112), hereafter referred to as the Interim Action ROD, was signed by the U.S. Department of Energy (DOE), Richland Operations Office (DOE-RL) (also known as RL); the Washington State Department of Ecology (Ecology); and the U.S. Environmental Protection Agency (EPA). The 1999 Interim Action ROD addressed the source waste sites, the shoreline site, the petroleum hydrocarbon site, and the groundwater. The RCRA TSD waste sites are addressed in a separate ROD. The 1999 Interim Action ROD required pump-and-treat for strontium-90, institutional controls (ICs), and further technology evaluation for strontium-90 removal from groundwater. The original *Remedial Design/Remedial Action Work Plan for the 100-NR-2 Operable Unit* (DOE/RL-2001-27, Rev. 0), hereafter referred to as the RD/RAWP Rev. 0, provided details necessary for implementation of this remedy.

Based on the results of the strontium-90 technology evaluations and subsequent field evaluations, the 1999 Interim Action ROD was amended (hereafter referred to as the Interim Action ROD Amendment) on September 30, 2010. The Interim Action ROD Amendment replaces the strontium-90 groundwater pump-and-treat system with a subsurface apatite permeable reactive barrier (PRB). The *Proposed Plan for Amendment of the 100-NR-1/NR-2 OU Interim Action Record of Decision* (DOE/RL-2009-54) describes the rationale for amending the 1999 Interim Action ROD. This revised RD/RAWP (Rev. 1) provides information associated with development of a remedial design (RD) and remedial action (RA) implementation strategy for the remedy selected in the Interim Action ROD Amendment for the100-NR-2 Groundwater OU.

The RD establishes the general size, scope, and character of the project and identifies the technical requirements of the RA. The RD/RAWP (Rev. 1) is the basis for implementing the design. It details the work elements, performance measurements, construction management and oversight, schedules and cost for the design, and construction and operation of the remedy. Implementation of the remedy selected in the Interim Action ROD Amendment, in conjunction with final actions to be identified in a final ROD scheduled for completion in 2013, will help achieve the default[1] ambient water quality standard of 8 pCi/L for strontium-90 in the hyporheic zone and river water column by 2016 (TPA Milestone Target Date M-016-110-T03), thus providing increased protection for the Columbia River.

1.1 Purpose

In accordance with the TPA, a remedial design report (RDR) and a remedial action work plan (RAWP) are required to describe how the selected remedy and related activities specified in the Interim Action ROD Amendment will be implemented. The purpose of RD/RAWP (Rev. 1) is to describe the design and implementation of the interim RA pertaining to the 100-NR-2 Groundwater OU as described in the Interim Action ROD Amendment. A sampling and analysis plan (SAP) is also required for selected

[1] Because there is no promulgated federal or state ambient water quality standard for strontium 90, the Tri-Parties have agreed to use the DWS of 8 pCi/L as the RAG for the hyporheric zone.

remedies. The SAP requirements for the 100-NR-2 OU are described in DOE/RL-2009-58, *100-N Area Integrated Groundwater Sampling and Analysis Plan.*

This document supersedes Rev. 0 of this RD/RAWP (*Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit* [DOE/RL-2001-27]), which was prepared primarily to describe the RD and RA requirements for the expedited response action (ERA) pump-and-treat system that operated between 1995 and 2006.

DOE is the lead agency responsible for performing the Interim Action ROD Amendment. This RD/RAWP (Rev. 1) is being submitted to the lead regulatory agency (Ecology) in accordance with Section 11.6 of the *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b), also known as the TPA Action Plan, which states: "Within 180 days of the last ROD signature for CPP units, or CAD and ROD signature for R-CPP units, or an alternative period designated in the ROD or in the CAD and ROD, an RD/RA (or CMI and RD/RA) work plan including schedule, along with a milestone change package, shall be submitted for lead regulatory agency review and approval as specified above." EPA is the non-lead regulatory agency.

1.2 Scope

This RD/RAWP includes the RAs that will be implemented to meet the requirements of the Interim Action ROD Amendment. The amended interim action remedy for 100-NR-2 Groundwater OU is a combination of in situ groundwater treatment using an apatite PRB, monitored natural attenuation (MNA), and ICs. The interim RA described in this RD/RAWP is specific to strontium-90 and was designed such that enough apatite will be emplaced to provide for a 300-year design life. Final actions to address radionuclide and nonradionuclide contaminants of concern (COCs) identified in the Interim Action ROD will be described in a remedial investigation (RI)/feasibility study (FS) and a Proposed Plan scheduled for completion in 2012.

The TPA specifically lists the RDR and the RAWP as two separate documents. This document streamlines this requirement by combining the RDR and RAWP into a single submittal. This document addresses the following:

- Installation of the apatite PRB
- Decommissioning of the existing treatment components for the 100-NR-2 Groundwater OU pump-and-treat system installed in 1994 under an ERA
- ICs for 100-N
- Groundwater monitoring and reporting to assess effectiveness of the apatite PRB in reducing strontium-90 flux to the river
- Other RA and operations and maintenance (O&M) activities necessary to maintain the integrity of the apatite PRB until a final remedy is selected and implemented

RD and RA activities for the 100-NR-1 OU are presented in DOE/RL-2005-93, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*. RD and RA activities associated with the RCRA TSD units are presented in DOE/RL-2000-16, *Remedial Design Report/Remedial Action Work Plan for the 100-NR-1 Treatment, Storage, and Disposal Units*. However, because of the RCRA permit requirements (*Hanford Facility Resource Conservation and Recovery Act Permit for Treatment, Storage, and Disposal of Dangerous Waste Permit* [Ecology, 1994]) and the potential for impact to the groundwater from the source and TSD waste sites, all interim RAs and final RAs in 100-N will require a coordinated effort, as described in the Interim Action ROD Amendment.

An RI/FS work plan for the entire 100 Area was prepared in 2008 and approved in 2010 (*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* [DOE/RL-2008-46]). This document outlined the overall process for developing and completing an RI/FS, a Proposed Plan, and a final ROD for each Hanford 100 Area site. Separate addendums to the RI/FS work plan, specific to each of the 100 Area sites, were then prepared. The 100-N site is addressed in DOE/RL-2008-46-ADD5, Draft B, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 5: 100-NR-1 and 100-NR-2 Operable Units*. This document identifies specific data needs necessary to select a final RA for the 100-NR-1 and 100-NR-2 OUs.

1.3 Site Description and Background

The 100-N description and historical background are summarized in this section, and a 100-N area map provided in Figure 1-2. The information presented in this section was compiled from the following references:

- *Limited Field Investigation Report for the 100-NR-2 Operable Unit* (DOE/RL-93-81)
- *Qualitative Risk Assessment for the 100-NR-2 Operable Unit* (BHI-00055)
- *Corrective Measures Study for the 100-NR-1 and 100-NR-2 Operable Units* (DOE/RL-95-111)
- *N-Springs Expedited Response Action Performance Evaluation Report* (DOE/RL-95-110)
- *Proposed Plan for Interim Remedial Actions at the 100-NR-1 Source Sites Operable Unit and the 100-NR-2 Groundwater Operable Unit* (DOE/RL-96-102)
- *Letter Report for Modeling Evaluation of N-Springs Barrier and Pump-and-Treat Systems* (DOE/RL-94-132)
- *Strontium-90 Adsorption-Desorption Properties and Sediment Characterization at the 100-N Area* (PNL-10899)
- *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington* (EPA/541/R-99/112)
- *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit* (DOE/RL-2001-27, Rev. 0)
- *Evaluation of Strontium-90 Treatment Technologies for the 100-NR-2 Groundwater Operable Unit Letter Report* (Fluor Hanford and CH2M HILL, 2004)
- *Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump & Treat Operations* (DOE/RL-2004-21)
- *Proposed Plan for Amendment of 100-NR-1/NR-2 Interim Action Record of Decision* (DOE/RL-2009-54)

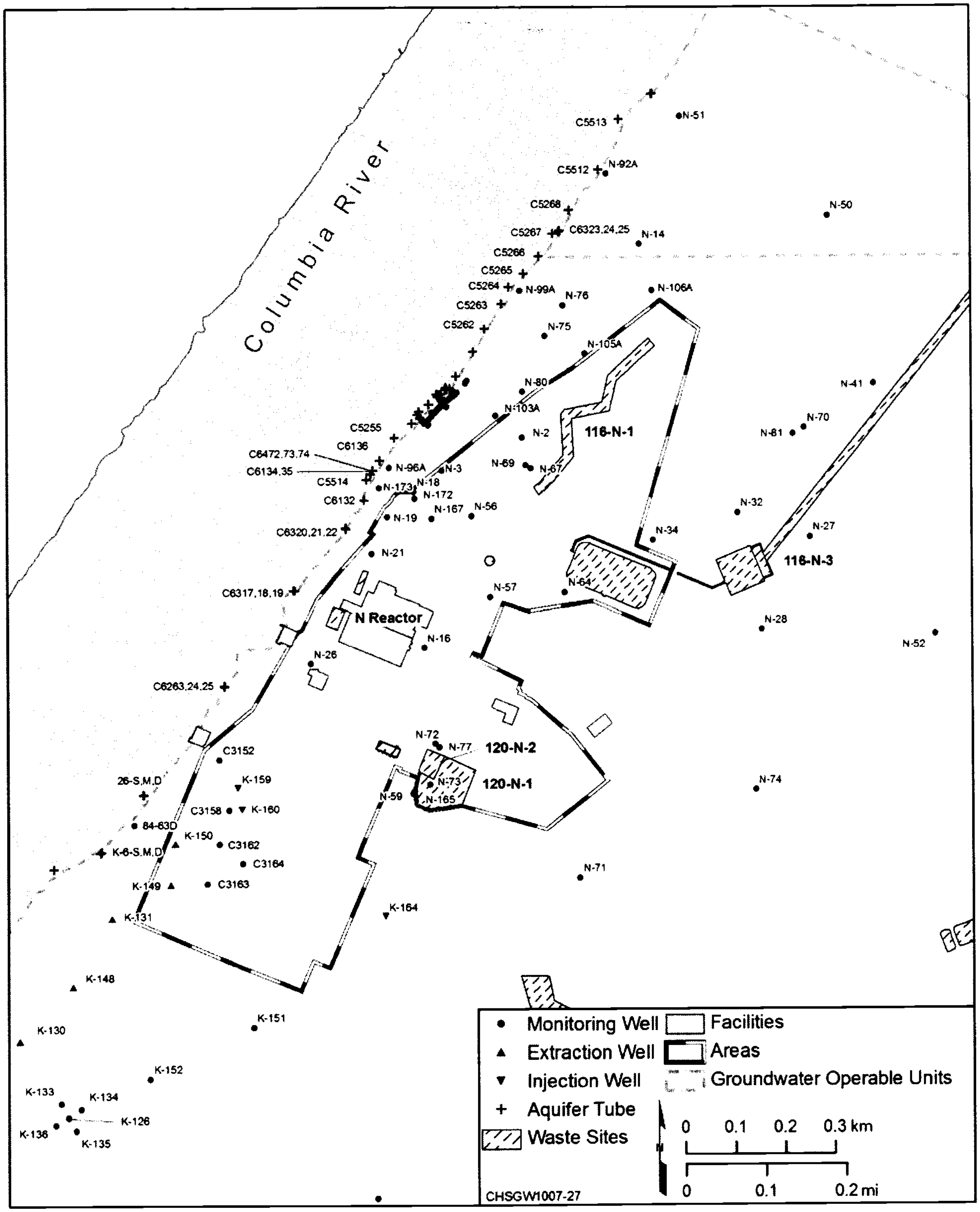

Figure 1-2. 100-N Area Site Map

- *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit* (DOE/RL-2010-29)
- *Jet Injection Design Optimization Study for the 100-NR-2 Groundwater Operable Unit* (DOE/-RL-2010-68)
- *Hanford Sitewide Groundwater Monitoring and Performance Report for 2009* (DOE/RL-2010-11)

The following summary of the 100-N operations was adapted from DOE/RL-95-110:

> *In 1963, the 1301-N Liquid Waste Disposal Facility (LWDF), located approximately 244 m from the Columbia River, was constructed for the disposal of water from the N Reactor primary cooling loop, spent fuel storage basins, and other reactor-related sources. At the start of the reactor's operation, monitoring wells were installed between the LWDF and the Columbia River. Mobile contaminants (e.g., tritium) were observed almost immediately in the N-Springs [that appeared along the river bank]. The 1301-N LWDF received approximately 7,950 L/min of radiologically contaminated water, causing a 6-m-high [groundwater elevation] mound to form on the water table [underlying the LWDF]. The near-field [groundwater] flow system [that formed beneath the LWDF] was radial [extending outward] from the LWDF, with discharged liquids ultimately reaching the river.*

By the late 1970s, elevated levels of strontium-90, which moves much more slowly than tritium, were detected in the groundwater near the river. To mitigate strontium-90 entry into the river, the 1325-N LWDF was constructed further inland from the river and placed into partial service in 1983 and full service in 1985. The flow rate to the 1325-N LWDF was estimated at 1,514 L/min (400 gal/min) from 1983 to 1985, 5,300 L/min (1,400 gal/min) in 1986, and approximately 1,325 L/min (350 gal/min) from 1986 to 1991. Discharges to the 1301-N and 1325-N LWDFs[2] ceased in 1985 and 1991, respectively (DOE/RL-95-110).

The principal radionuclide contaminants in groundwater are tritium and strontium-90. The primary radionuclide inventory (DOE/RL-94-132, *Letter Report Modeling Evaluation of N-Springs Barrier and Pump-and-Treat Systems*) discharged to the LWDFs included the following estimates:

- Approximately 2,997 Ci of strontium-90 was contained in the liquid effluent discharged to the LWDFs during N Reactor operation (DOE/RL-2008-46-ADD5, Draft B).
- Of the estimated 2,997 Ci of strontium-90 initially present in the liquid effluent, approximately 46 Ci of strontium-90 (decayed to 1995) was estimated to have entered the Columbia River through groundwater flow.
- Based on the total inventory of strontium-90 discharged to the LWDFs, less than that which entered the Columbia River, approximately 1,866 Ci (decayed to 1995) remained within the LWDFs, vadose zone soil and the underlying unconfined aquifer.

In the 1996 report, *Strontium-90 Adsorption-Desorption Properties and Sediment Characterization at the 100-N Area* (PNL-10899), the amount of strontium-90 present within the groundwater plume was calculated. The report estimated a total strontium-90 inventory of 88.8 Ci (decayed to 1996), with 88 Ci bound to the aquifer sediment and 0.8 Ci present in groundwater. A second estimate on the amount of strontium-90 present within the plume was provided in BHI-00469, *Hanford Sitewide Groundwater*

[2] The 1301-N and 1325-N LWDFs (active designation) are also referred to in this document by their respective 116-N-1 and 116-N-3 TSD post remediation designations.

Remediation Strategy—Groundwater Contaminant Predictions. The report estimated 75 to 88 Ci (decayed to 1995) of strontium-90 within the aquifer matrix, of which 0.5 to 0.8 Ci is dissolved in groundwater. These estimates suggested that the remaining 1,791 to 1,778 Ci of strontium-90 were contained in the LWDFs or underlying vadose zone. The estimates on the amount of strontium-90 remaining in the vadose zone and aquifer vary due to differences in the decayed to dates and the overall estimation method.

Other nonradiological contaminants were also discharged to the LWDFs. A list of contaminants that were contained in the liquid effluent discharged to the LWDFs, and that are routinely monitored for in groundwater, are provided in WHC-SD-EN-TI-023, *Hydrologic Information Summary for the Northern Hanford Site*. These contaminants included chromium, nitrate, sulfate, and total petroleum hydrocarbons. The need for and scope of the final RAs necessary to address the nonradiological contaminants will be described in the RI/FS Report and Proposed Plan scheduled for completion in 2012.

1.3.1 Response Action Status

Because of concern regarding the release of strontium-90 to the Columbia River, Ecology and EPA issued the *N Springs Expedited Response Action Cleanup Plan* (Ecology and EPA, 1994) to DOE-RL on September 23, 1994. The ERA required DOE-RL to take immediate action, which consisted of installing and operating a groundwater pump-and-treat system and a sheet pile barrier wall at N-Springs.

By a letter dated March 23, 1995, Ecology and EPA agreed that a sheet pile construction test in December 1994 showed that the installation of the jointed hinge sheet pile wall could not be achieved in the manner specified (Stanley and Sherwood, 1995). Ecology and EPA directed DOE-RL to proceed with the installation of the pump-and-treat system. Additionally, DOE-RL was directed to continue assessing accurately the flux of strontium-90 to the river, further characterize geologic and hydrologic conditions, and assess design and installation alternatives related to modified barriers and expected performance.

The N-Springs pump-and-treat system, which was completed in August 1995, began full operation in September 1995, meeting TPA Milestone M-16-12D. The 1999 Interim Action ROD required continued operation of the pump-and-treat system in accordance with the design configuration described in DOE/RL-97-34, *N-Springs Pump and Treat System Optimization Study*; and continued groundwater monitoring, not related to the performance of the ERA pump-and-treat system, as interim actions. The objectives for the ERA were to substantially reduce the flux of strontium-90 to the Columbia River and to obtain data sufficient to establish final RAs. Additional requirements were included in the 1999 Interim Action ROD to address petroleum hydrocarbon contaminated groundwater, assess strontium-90 impacts on aquatic and riparian receptors, and evaluate technologies for strontium-90 removal from groundwater.

The actions described in the following subsections were implemented to fulfill the requirements of the Interim Action ROD.

1.3.1.1 Pump-and-Treat Operations

The pump-and-treat system included four extraction wells, a treatment system for strontium-90 removal, and two injection wells to return the treated water to the aquifer. This system operated between 1995 and 2006. Approximately 1.1 billion L (305 million gal) of groundwater containing 1.8 Ci of strontium-90 were removed from the aquifer and treated. The 0.2 Ci of strontium-90 removed each year by pump-and-treat operations was estimated to be 10 times less than the amount removed by natural radioactive decay (DOE/RL-2004-21). This amount represented a small percentage of the 1,866 Ci (decayed to 1995) of strontium-90 estimated to remain in the subsurface. Because the pump-and-treat system had limited success in removing strontium-90 from the aquifer, as a result of strontium's strong affinity for adhering to aquifer sediments, the system was placed in a standby mode in March 2006 by TPA Change Request M-16-06-01 approved by DOE, EPA, and Ecology (Ecology et al., 1989a).

The original ERA performance monitoring requirements were modified twice using TPA change control procedures. The first modification occurred under TPA Change Control Form M-16-96-04, which was approved on August 2, 1996. This agreement was superseded by 100 National Priorities List Agreement/Change Control Form, Control No. 113, which was approved on March 25, 1997. It required monitoring strontium-90 concentrations in the pump-and-treat system influent and effluent. Collecting water quality data from wells or similar monitoring sites was not required under this agreement to monitor the performance of the pump-and-treat system.

Additional groundwater monitoring that is not related to the performance of the ERA pump-and-treat system includes obtaining data to support remediation decisions under CERCLA, TSD facility requirements under RCRA, the Interim Action ROD requirement for petroleum hydrocarbon monitoring, and sitewide surveillance under the *Atomic Energy Act of 1954*. A consolidated program to meet these requirements has been developed, and an agreement is documented in the TPA Change Control Form M-15-96-08, dated October 1996.

The ERA performance monitoring program and the consolidated groundwater monitoring program are described in the *N Springs Expedited Response Action Performance Monitoring Plan: Update* (BHI-00164). This proposed monitoring program has since been updated as described in DOE/RL-2009-58, Draft A.

1.3.1.2 Petroleum Hydrocarbon Contaminated Groundwater

Petroleum hydrocarbon contamination has been observed in 100-N monitoring Wells 199-N-17 and 199-N-18 as free product and as a dissolved phase in the groundwater. Total petroleum hydrocarbon data reported in DOE-RL-2010-11 indicate that the total petroleum hydrocarbon concentration in 100-NR-2 groundwater is decreasing. However, the Interim Action ROD requires remediation of free floating product observed in these two wells (or other 100-N wells). A passive removal method (Smart Sponge®) was initiated in 2003 to remove the small amount of free product in Well 199-N-18. The approach was taken because the layer of floating petroleum was too thin for removal by active methods. A total of 9.2 kg of free product was removed from Well 199-N-18 from 2003 through 2009. The rate of petroleum recovery has decreased from 3.5 kg in 2004 to 0.13 kg in 2009. Well 199-N-17 has gone dry and was taken out of service/decommissioned.

Remediation of the petroleum source waste sites is addressed in DOE/RL-2005-93. A pilot test was commissioned in 2009 to evaluate the effectiveness of bioventing to address petroleum hydrocarbon contamination (primarily No. 2—diesel fuel oil and No. 6—Bunker C) present in vadose zone soil. Seven pilot test wells were drilled and are being injected with air to stimulate naturally occurring microorganism growth and hydrocarbon treatment. If the pilot test is successful, the results will be used to design and install two full-scale in situ bioremediation systems for treatment of petroleum hydrocarbon contaminated soil in 100-N. The RI/FS report and proposed plan scheduled for completion in 2012 are expected to address this remedy component.

1.3.1.3 Aquatic and Riparian Contaminant Receptors

The 1995 ecological qualitative risk assessment (QRA) presented in BHI-00055 focused on the hypothetical effects of contaminants on selected aquatic organisms in or near the Columbia River. The scope of this assessment was limited; therefore, the 1999 Interim Action ROD included a provision

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for a more thorough evaluation of impacts to ecological receptors in the shoreline area. Cadmium, lead, and zinc were identified in the QRA as contaminants of potential ecological concern.

Strontium-90 at the Hanford Site and its Ecological Implications (PNNL-13127) was published in May 2000. This report presented an assessment of the potential for ecological impacts to salmon embryos.

An ecological risk assessment was conducted in accordance with an approved SAP (DOE/RL-2005-22, Rev. 0) and the results initially presented in DOE/RL-2006-26, Rev. 0, *Aquatic and Riparian Receptor Impact Information for the 100-NR-2 Groundwater Operable Unit*. This document was later updated and reissued as DOE/RL-2005-22, Rev. 1 Reissue. The evaluation presented in this document concluded that strontium-90 concentrations in Asiatic clams in along the 100-N shoreline were elevated relative to the upstream Vernita reference area. However, the estimated radiological dose for all biota evaluated were less than United States and international thresholds. Soil concentrations for several metals in the strontium-90 plume area exceeded thresholds developed for birds. Additionally, there was little indication of adverse effects from strontium-90 in the health status indicators surveyed during the sampling efforts.

Indicators of potential adverse effects associated with metals contamination were identified along a section of shoreline (approximately 150 m [492 ft] long) in the vicinity of a diesel (petroleum hydrocarbon) contaminated area resulting from the 1966 spill. Water quality sampling data from aquifer tubes installed 10 cm (3.9 in.) beneath the riverbed indicate that the impacted area contained low dissolved oxygen concentrations and elevated levels of dissolved iron and manganese that exceeded water quality benchmarks for the protection of aquatic life. Low dissolved oxygen concentrations in combination with elevated iron and manganese levels suggest that microbial decomposition of petroleum hydrocarbons is occurring. Additional sampling to be conducted under DOE/RL-2009-42 and DOE/RL-2010-69, *Sampling and Analysis Plan for the 100-NR-2 Operable Unit River Pore Water Investigation*, will be used to obtain the information needed to provide further evaluation of petroleum hydrocarbon related contaminants and to select a remedy for this portion of 100-N.

Along the shoreline, riprap material was placed over portions of the riverbank to reduce the potential for human and ecological receptor contact with contaminated groundwater seeps and springs. The large basalt boulders were emplaced in 1984. Steel casings, referred to as seep wells, were installed through the riprap to provide sampling access. The seep wells have been sampled per historic and current environmental monitoring requirements.

Assessment of Apatite Injection at 100-NR-2 for Potential Impact on Threatened and Endangered Species (PNNL-SA-75348) presents an evaluation of the potential impact that unreacted apatite forming minerals may have on threatened or endangered species residing in the near-shore river environment at 100-N. Three species of fish from the Hanford Reach are covered under the *Endangered Species Act of 1973*: the upper Columbia River spring Chinook salmon, the upper Columbia River steelhead, and the bull trout. The assessment concluded that only out-migrant upper Columbia River spring Chinook salmon smolts and upper Columbia River steelhead smolts are likely to be found along the 100-N shoreline during May and June. It was also concluded that adult bull trout may be found in the river, but occurrences are rare and their presence along the 100-N shoreline would be incidental and rare. Potential impacts resulting from the migration of unreacted chemicals (e.g., phosphate, sodium, calcium, chloride, and citrate) with groundwater to the Columbia River were evaluated by comparing post-injection ion concentration data from groundwater wells and aquifer tubes with toxicity response values for aquatic organisms obtained from published laboratory studies. Because dissolved ions temporarily approached the lower concentration range of semi-acute (7-day exposure) toxicity levels in aquifer tubes, it was determined there is the potential for elevated dissolved ions to create osmotic stress in fish that reside in the near-shore habitat. However, several mitigating factors (including mixing with surface water and migratory behavior in smolts) may preclude extended exposure. In addition, well and aquifer tube monitoring data and surface water data were reviewed for the presence of trace metals, chloride, and conductivity to evaluate potential impacts from ions or metals that are mobilized from sediments by the high concentrations of ions in the injected material. It was concluded that post-injection monitoring data in the 100-N near-shore environment do not indicate exposure to elevated concentrations of toxic metals and, under existing conditions, mixing of groundwater and surface water in the near-shore environment is of sufficient magnitude to render contaminant concentrations to levels indiscernible from river background.

1.3.1.4 Technology Evaluation for Strontium-90

As required by the Interim Action ROD, DOE conducted a comprehensive review of strontium-90 treatment technologies. Under the Innovative Treatment and Remediation Demonstration (ITRD) Program, the Technical Advisory Group (TAG) for 100-N completed a remedial options evaluation (ITRD, 2001) in November 2001. Based on the evaluation presented in this document, the TAG recommended that MNA, soil flushing, phytoremediation, stabilization by phosphate injection, impermeable barriers (sheet pile and cryogenic), and treatment barriers (clinoptilolite) be evaluated further for strontium-90 remediation. Subsequent evaluations and field trials led to the elimination of soil flushing and sheet pile barriers as viable technologies for the 100-NR-2 OU.

A letter report, FH-0403540, "Evaluation of Strontium-90 Treatment Technologies for the 100-NR-2 Groundwater Operable Unit," was published in October 2004. This document and related public workshop comments (December 2004), together with the ITRD Report, satisfied the technology evaluation requirement specified in the Interim Action ROD. An evaluation of the most promising treatment alternatives and proposed a path forward for testing and selecting an alternative was included in FH-0403540. Four PRB technologies were considered: vertical hydrofracture, aqueous injection, air injection, and trenching. It was determined that barrier walls constructed via trenching were not feasible along the shoreline where a PRB would provide the greatest benefit. The remaining technologies were evaluated based on effectiveness, implementability, reduction of near-shore contamination, public acceptance, risk, and cost.

Overall, the technologies compared closely; therefore, a single approach was not clearly identified. However, because aqueous injection has the potential to treat the sediments at the shoreline, the Letter Report recommended that it be the first technology tested in the field. The Letter Report also reiterated the conclusion from the ITRD (ITRD, 2001) that, while MNA may be appropriate for portions of the plume far from the river, it will not limit current discharges of strontium-90 to the river. Phytoremediation was retained for consideration in conjunction with a barrier, but it was not regarded as a stand-alone alternative for the shoreline area.

As recommended in the Letter Report, a treatability test plan (TTP), (DOE/RL-2005-96, *Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit*, Rev. 0, Reissue) was prepared to implement field testing to evaluate strontium-90 sequestration in the saturated zone using apatite. In addition to the initial TTP, three separate addenda to the TTP were approved, each outlining additional testing to evaluate apatite emplacement methods or treatment areas. The first addendum (DOE/RL-2005-96-ADD1, *Treatability Test Plan Addendum for 100-NR-2 Groundwater Operable Unit*) describes injection of a high concentration aqueous solution to follow the initial low concentration injection into the saturated zone. The second addendum (DOE/RL-2005-96-ADD2, *Treatability Test Plan Addendum for 100-NR-2 Groundwater Operable Unit*) described the approach for infiltration of an aqueous solution into the vadose zone along the 100-N shoreline. The third addendum (DOE/RL-2005-96-ADD3, *100-NR-2 Apatite Treatability Test Plan Implementation*) described the approach for the jet injection of apatite into the vadose zone.

Activities completed to date in support of DOE/RL-2005-96 and its addendums included:

- Laboratory scale studies were conducted to demonstrate in situ apatite formation and strontium-90 sequestration proof-of-principle, characterize apatite formation and strontium-90 sequestration mechanisms important to development of a pilot field scale test design, and optimize the calcium-citrate-phosphate amendment formulation to achieve site remedial objectives. The laboratory bench scale studies are documented in PNNL-16891, *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO_4 Solution Injection and Strontium-90 Immobilization in 100-N Sediments*, and in PNNL-SA-70033, *100-NR-2 Apatite Treatability Test FY09 Status: High Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization, Interim Report*.

- A pilot test in 2006 involving aqueous injection of a low concentration calcium-citrate-phosphate aqueous solution was initiated; in 2007, a PRB was emplaced along a 90 m (300 ft) section of the 100-N shoreline where the highest strontium-90 concentrations had been observed. The objectives for the pilot test were to determine whether the injection resulted in apatite precipitation in the target zone and reduced strontium-90 concentrations in groundwater, and to determine the injection volume needed for a 9 m (30 ft) well spacing. These test activities were reported in PNNL-17429, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization*.

- Sediment core samples collected following the initial low concentration treatments were analyzed for apatite content and compared with the apatite formation design target for this initial treatment. Although the apatite contents were small, they were sufficient to demonstrate the formation of phosphate mineral phases. The overlapping zone between adjacent wells received an average treatment of 110 percent of the targeted apatite content within the Hanford formation and 30 percent treatment within the Ringold Formation (PNNL-18303, *Sequestration of Strontium-90 Subsurface Contamination in the Hanford 100-N Area by Surface Infiltration of a Ca-Citrate-Phosphate Solution*).

- In 2008, the pilot test sites used for the initial low concentration injections were used for the high concentration apatite injection to assess the side effects of the process prior to continuing with the remaining barrier well injections. Preliminary results of the high concentration injections were reported in an interim report (PNNL-SA-70033). The objectives for the TTP were met after the high concentration injection. Apatite formation was confirmed in the target zone through collection of soil cores. Target strontium-90 concentration reductions of 90 percent were confirmed though groundwater monitoring at four compliance well locations. Injection volume requirements were determined based on amendment arrival responses observed during the injections (PNNL-SA-70033). In addition to the specified injection volumes, it was determined that, due to the difference in hydraulic conductivity in the Ringold Formation and Hanford formation, installation of 44 injection wells targeting only the lower portion of the contaminated zone (Ringold Formation) would be needed to provide effective amendment coverage over the downstream section of the PRB. It was also determined that, in addition to the requirement that Hanford formation treatments be performed during the highest Columbia River stage conditions (to treat the full saturated thickness), treatments of only the Ringold Formation should occur during low Columbia River stage conditions to achieve an acceptable radial distribution of apatite forming minerals. A preliminary evaluation based on sediment core samples collected in November 2009 was presented in *Hanford 100-N Area In Situ Apatite and Phosphate Emplacement by Groundwater and Jet Injection: Geochemical and Physical Core Analysis* (PNNL-19524).

- In 2009, wells were installed in the vadose zone to perform infiltration tests near the PRB. The test objectives were to evaluate infiltration of an aqueous solution from near-ground surface through the vadose zone, and to determine the type of monitoring equipment necessary to monitor the infiltration front. Previous water based infiltration evaluations have indicated that compaction of road-bed materials may severely limit infiltration rates along the shoreline. In this test plan, the upper 1 m (3 ft) of roadbed would be excavated to increase infiltration. Laboratory experiments were conducted to determine whether the unsaturated Hanford formation is conducive to formation of apatite through surface application of reagents (PNNL-18303). These 2-dimensional infiltration experiments showed that the infiltration rate, concentration of the calcium-citrate-phosphate solution, and addition of water after solution infiltration, all affected apatite precipitation in the vadose zone. The most effective method found for emplacing apatite in high hydraulic conductivity regions was air/ surfactant injection where the calcium-citrate-phosphate was present in a foam. This study showed that while it is difficult to emplace apatite accurately in the vadose zone, because of the infiltration rate control required, it is possible to use this method to sequester strontium-90 in the subsurface.

- In 2009, a field demonstration was completed to evaluate potential strategies for jet injection of three different media: a phosphate only solution, pre-formed apatite, and phosphate combined with pre-formed apatite. The objectives for these demonstrations were to evaluate delivery technologies and effectiveness. The injections were conducted upgradient of the existing apatite PRB within a moderate strontium-90 concentration region of the plume. The solutions were injected into the vadose zone and unconfined aquifer. Results from collected sediment cores indicate that jet injection is a viable method for emplacement of phosphate and pre-formed apatite in the vadose zone. These cores also showed that jet injection is a viable method for emplacement of phosphate and pre-formed apatite in the vadose zone, with injected chemicals meeting the injection target goal within 1.2 m (4 ft) of the injection point (PNNL-19524).

1.3.1.5 Other Response Actions

Interim actions were also taken to address soil contamination. As specified in the 100-NR-1 TSD interim ROD, the top 4.6 m (15 ft) of contaminated soil was removed at the 116-N-1 and 116-N-3 LWDFs and transported to the 200 Area for disposal at the Environmental Restoration Disposal Facility (ERDF). As of March 2010, approximately 522,200 tons of contaminated soil and debris had been removed from 100-N. Approximately 250,000 and 154,600 tons of this material was associated with the 116-N-1 and the 116-N-3 LWDFs, respectively.

In addition to the 116-N-1 and 116-N-3 LWDFs, the Interim Action ROD identified 80 other waste sites in the 100-NR-1 OU requiring interim RA. Cleanup of these waste sites is being implemented in an order of priority as established by the Tri-Parties. Additional waste sites have since been discovered and the total number of waste sites now stands at 185. As of March 2010, 129 of the waste sites have already been closed or are scheduled for cleanup in the fiscal year (FY) 2010 and 2011 time frame.

A RI/FS work plan for the entire 100 Area was prepared in 2008 and approved in 2010 (DOE/RL-2008-46). This document outlines the overall process that will be used for developing and completing an RI/FS, proposed plan, and final ROD for each of the 100 Area sites. Separate addendums were subsequently prepared for each 100 Area site. 100-N is addressed in DOE/RL-2008-46-ADD5, Draft B, which is still being negotiated with Ecology as of January 2011. This addendum identifies the data gaps necessary to select a final RA for the 100-NR-1 and 100-NR-2 OUs.

1.3.1.6 River Corridor Baseline Risk Assessment

A River Corridor Baseline Risk Assessment (RCBRA) was commissioned for the Columbia River Corridor, considering relevant sources of contamination, exposure pathways, and contaminants, to evaluate current and potential future risks to human health and the environment (HHE) posed by hazardous substance releases. The results of this work will be published in two volumes (Volume 1, Ecological Risk Assessment, and Volume 2, Human Health Risks) to support final cleanup decisions for the River Corridor. Risk managers will use the results from this RCBRA in conjunction with other information to develop cleanup decisions that will be protective of HHE. Final cleanup decisions applying to all portions of the River Corridor will be identified in proposed plans, which will undergo public review, and will be documented in RODs.

1.3.2 Physical Setting

The Hanford Site encompasses approximately 1,517 km^2 (586 mi^2) in the Columbia Basin of south-central Washington State (Figure 1-1). The 100-N area extends across an approximate 4 km^2 (1.6 mi^2) area, located along the Columbia River shoreline.

The topography in 100-N is relatively gentle but marked by the presence of a steep bluff approximately 21 m (70 ft) high along the river shoreline. 100-N is also characterized by the presence of numerous small rolling hills known as Mooli Mooli (Little Stacked Hills), which resulted from the cataclysmic flooding that occurred at the end of the Pleistocene Era, approximately 10,000 years ago.

Stratigraphic units of hydrogeologic significance in 100-N include the Elephant Mountain Basalt, the Ringold Formation, and the Hanford formation. As shown in Table 1-1 and Figure 1-3, the unconfined aquifer near the shoreline is composed of gravels and sands of the Ringold Formation and Hanford formation. The Ringold Formation is composed of several lithologic facies including Ringold unit E, which comprises the unconfined aquifer beneath the Hanford formation in 100-N, and the underlying Ringold upper mud unit. The base of the unconfined aquifer is defined by the top of the Ringold upper mud, which is considered an aquitard rather than an impermeable unit. Unit E is approximately 5 to 20 m (16 to 66 ft) thick, and the Ringold upper mud is approximately 17 to 29 m (56 to 95 ft) thick. The uppermost stratigraphic unit in 100-N is the Hanford formation. For most of 100-N, the Hanford formation extends from ground surface to just above the water table, and ranges from 6 to 23 m (20 to 75 ft) in thickness. Localized channels of Hanford gravels extend below the water table.

Table 1-1. Elevation and Thickness of Major Geologic Units beneath 100-N

Geologic Unit	Top Elevation (m)	Thickness Range (m)	Description
Hanford formation	122 to 145	6 to 23	Uncemented pebble-cobble gravel
Ringold unit E	118 to 128	5 to 20	Pebble-cobble gravel; variably cemented
Ringold upper mud	106 to 109	17 to 29	Silt and clay with minor sandy layers
Ringold unit C	80	3 to 5	Sand
Ringold Paleosol-Overbank Interval	75	38 to 43	Silt and sand
Ringold unit B	40	20 to 22	Sand
Ringold lower mud	10	30	Clay and silt
Ringold unit A	-20	4 to 8	Gravel
Elephant Mountain	-30	40 to 50	Basalt

Table 1-1. Elevation and Thickness of Major Geologic Units beneath 100-N

Geologic Unit	Top Elevation (m)	Thickness Range (m)	Description

Source: WHC-SD-EN-EV-027, 1993, *Hydrogeology of 100-N Area, Hanford Site, Washington,* and Hanford Well Information System, "Geologic Logs."

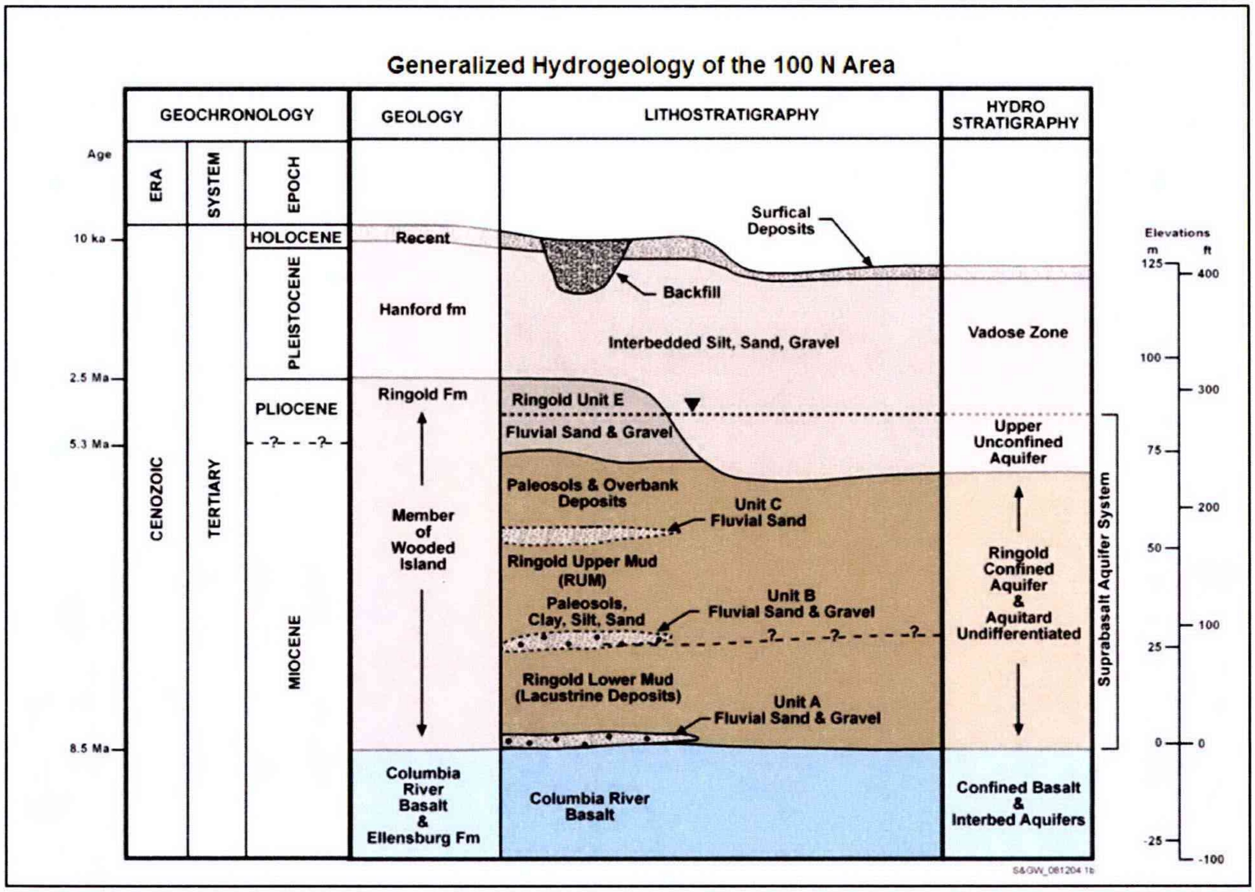


Figure 1-3. Generalized Geologic Stratigraphic Section for 100-N

The Hanford formation is more transmissive to water (3 to 10 times) than the underlying Ringold unit E. However, due to geologic heterogeneity, the hydraulic conductivity in both units is highly variable. Typical values of 15 and 182 m/d (19 and 597 ft/d) have been used for modeling purposes for the Ringold Formation and Hanford formation, respectively (HydroGeoLogic, Inc., 2001, *Strontium-90 Transport in the Near River Environment at the 100-N Area*).

Groundwater flow patterns and contaminant distribution in 100-N are described in several reports, including the Hanford Site groundwater reports (e.g., DOE/RL-2010-11). As shown in Figure 1-4, the general direction of groundwater flow in 100-N is north-northwest toward the Columbia River.

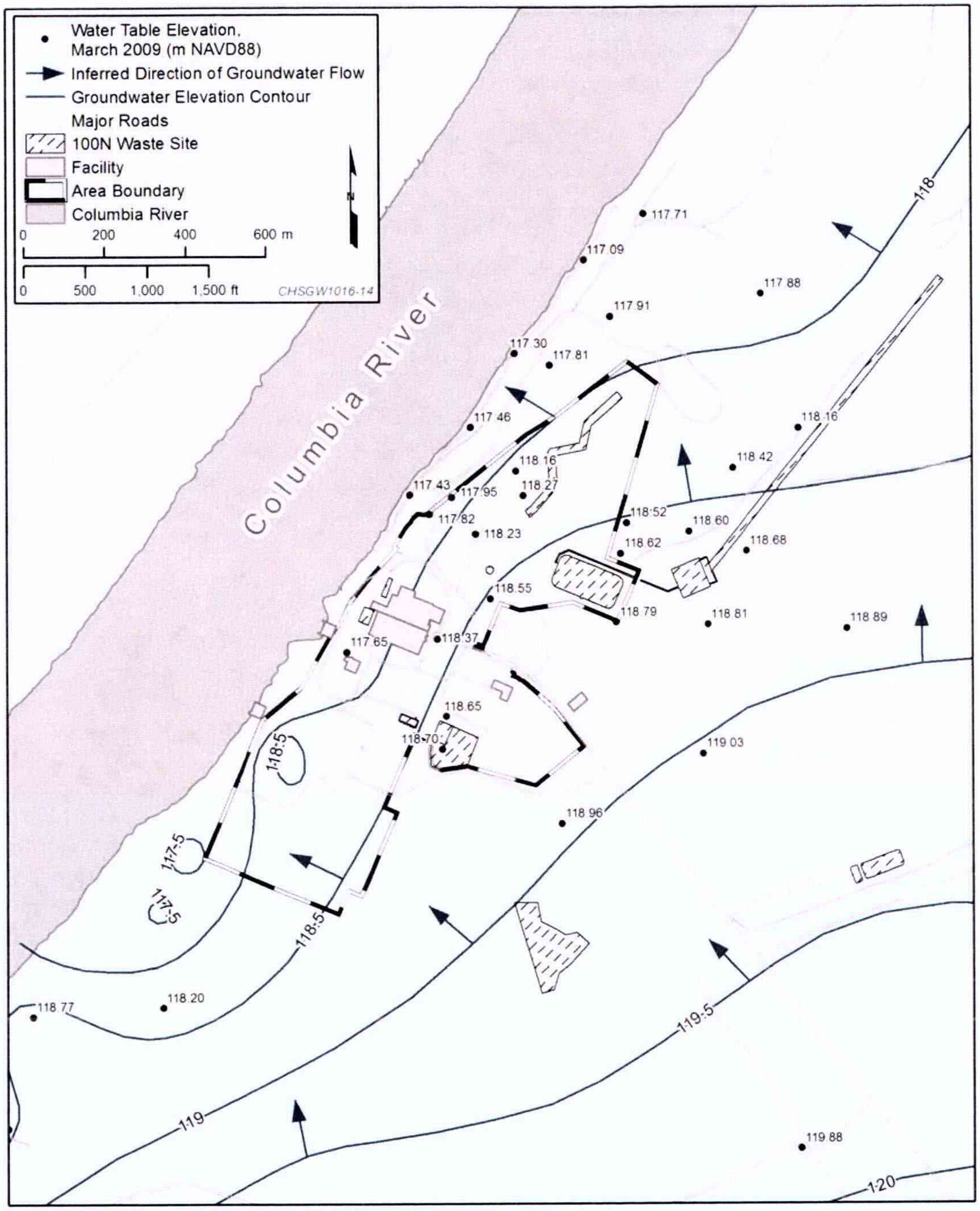


Figure 1-4. 100-N Water Table Map, March 2009

River stage fluctuations along the 100-N shoreline influence strontium-90 flux to the river. These fluctuations, which result from hydroelectric dam operating schedules and natural seasonal variations, create groundwater elevation changes in the shoreline environment. These changes, at times, reverse the hydraulic gradient, resulting in the temporary flow of water from the river to the aquifer instead of the natural flow direction where groundwater flows into the river. During high river stage, surface water moves into the river bank and exchanges with groundwater. During low river stage, the water drains back into the river. The zone where surface water and groundwater mixing occurs under high river stage conditions is located within tens of meters of the shoreline. As a result of the frequency of these gradient reversals, the volume of water that is exchanged between the river and the river bank is significantly greater than the volume of groundwater upwelling into the river as a result of the natural hydraulic gradient (DOE/RL-95-110). Historic seeps and springs, and groundwater upwelling are the primary pathway for strontium-90 entry into the Columbia River.

During historic 100-N Reactor operations, a groundwater elevation mound formed beneath the 1301-N and 1325-N LWDFs. The mound was approximately 6 m (20 ft) high and created large hydraulic gradients that increased groundwater flow rates toward the river. When the 100-N Reactor was operating, riverbank seepage was pronounced. Following shutdown of the 100-N Reactor and the LWDFs, the number of seeps and springs and their discharge volume decreased. Since 1997, there have been no visible seeps/springs along the 100-N shoreline where strontium-90 concentrations in groundwater are elevated (PNNL-19455).

1.3.3 Nature and Extent of Contamination

The radionuclide and chemical contaminated zones underlying the 116-N-1 and 116-N-3 waste sites, which represent the primary contaminant sources for the 100-NR-2 OU, resulted from 30 years of liquid effluent discharge. Of primary concern is the stontium-90 present in groundwater along the river shoreline. Strontium-90 is the primary COC in 100-N and the major focus of past and current groundwater interim actions. The portion of the strontium-90 groundwater plume with concentrations exceeding 8 pCi/L is estimated to be approximately 760 m (2,500 ft) wide at the river's edge (Figure 1-5) and extends inland approximately 900 m (3,000 ft). Concentrations greater than the 8 pCi/L remedial action goal (RAG) established in the Interim Action ROD occur across an estimated 58 ha (143 ac) area (DOE/RL-2010-11). The size and shape of the strontium-90 plume has varied little over the years, even during active pump-and-treat remediation. The plume currently has nearly the same areal extent and shape as was observed in 1996 prior to startup of the 100-N ERA pump-and-treat system.

As shown in the conceptual contaminant distribution model in Figure 1-6, the strontium-90 contaminated zone includes portions of the vadose zone that were effluent saturated during 100-N Reactor operations, and the underlying aquifer extending from the LWDFs to the Columbia River. The majority of the estimated 1,500 Ci (decayed to 2003) of strontium-90 remaining in 100-N resides in the vadose zone (DOE/RL-2004-21). Of the 72.8 Ci of strontium-90 present in the aquifer, an estimated 72 Ci are sorbed to the aquifer solids and approximately 0.8 Ci is present in groundwater. Strontium-90 has a much greater affinity for sediment than for water (i.e., a high distribution coefficient), so its rate of groundwater transport to the Columbia River is considerably slower than the actual groundwater velocity. The relative velocity of strontium-90 to groundwater is approximately 1:100 (DOE/RL-2005-96) or between 0.0005 and 0.009 m/day. Under current conditions, the estimated annual strontium-90 flux to the river from 100-N is 0.1 Ci per year (DOE/RL-95-110).

The historical presence of strontium-90 in the groundwater could have affected the environment along the river shore or out into the river sediments. Areas of groundwater upwelling exist in the near-shore river sediments. Water temperature and conductivity measurements were recently used to identify locations along the 100-N reach of the Columbia River where groundwater upwelling might be expected. Preliminary results from pore water sampling conducted between 2009 and 2010 (WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*) revealed detectable amounts of strontium-90 at a number of locations. However, the strontium-90 concentrations from most 100-N locations were below detection. Five samples revealed strontium-90 at concentrations ranging from 11 to 72 pCi/L, with concentrations of 11 and 17 pCi/L observed at two locations downstream from the 100-N outfall and spillway, which lies outside the known strontium-90 plume boundary. Additional evaluation of the pore water sampling information will be performed to support the 100-N RI/FS under DOE/RL-2010-69.

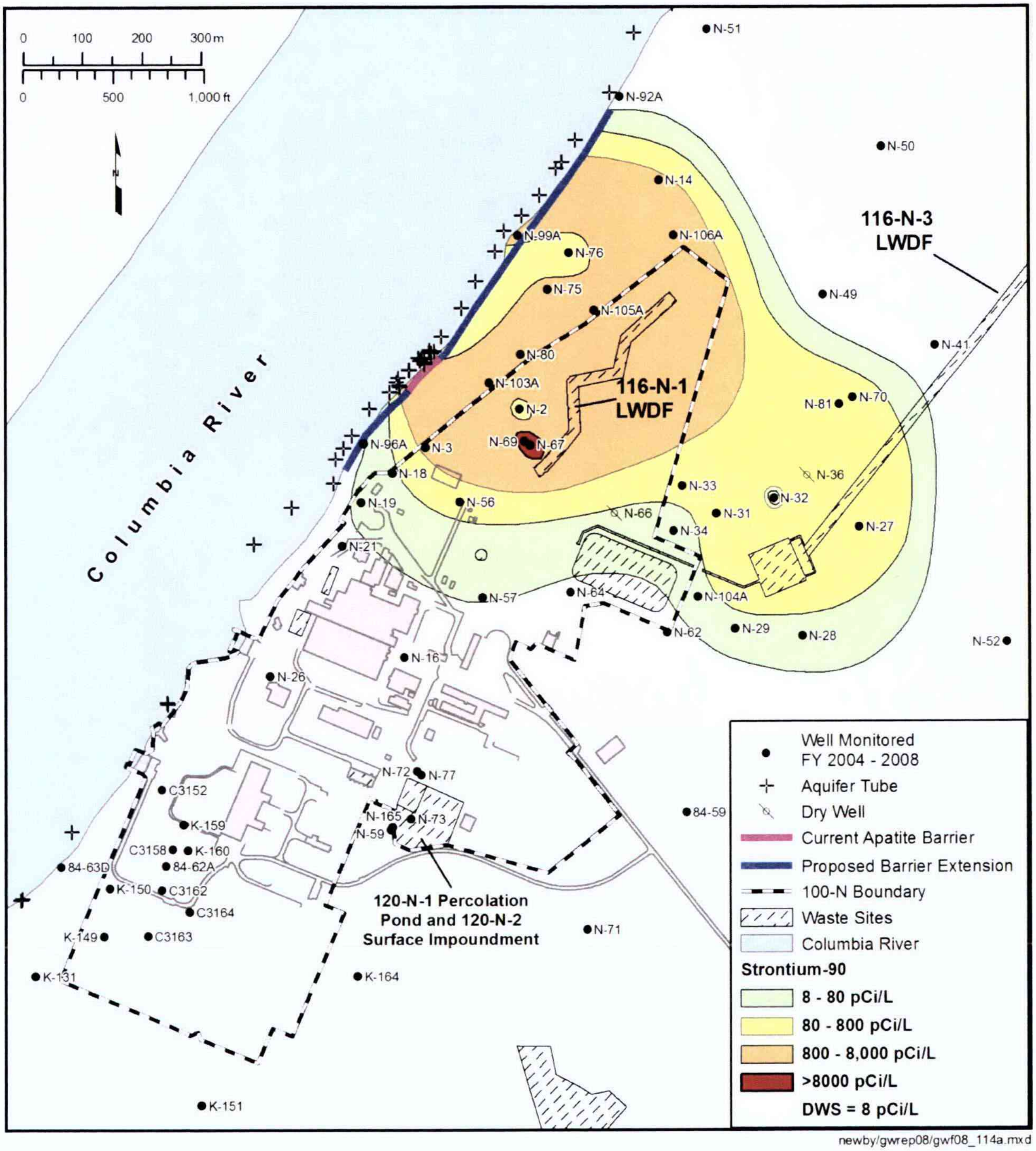


Figure 1-5. Strontium-90 Distribution in Groundwater (2008)

A majority of the strontium-90 remaining in the soil and groundwater is not expected to reach the Columbia River. As a result of its low mobility, a majority of the strontium-90 present in the inland portions of 100-N will naturally decay before reaching groundwater and the river. With a half-life of 28.6 years, it will take approximately 300 years for the maximum concentration of strontium-90 present in the aquifer at 100-N to decay to a concentration less than the 8 pCi/L RAG (Figure 1-7).

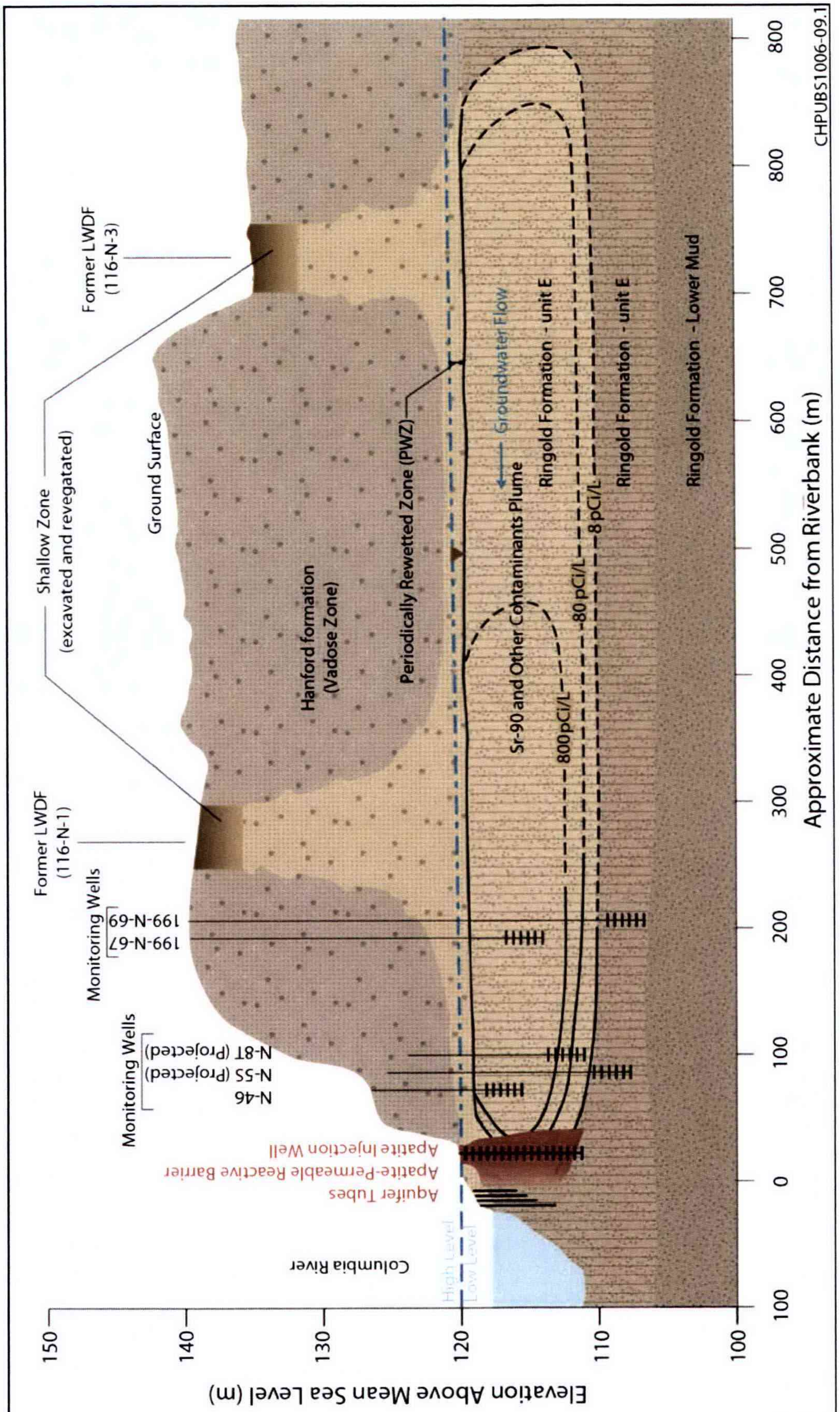


Figure 1-6. Conceptual Contaminant Distribution Model for Strontium-90 in the 100-NR-1/NR-2 Operable Units

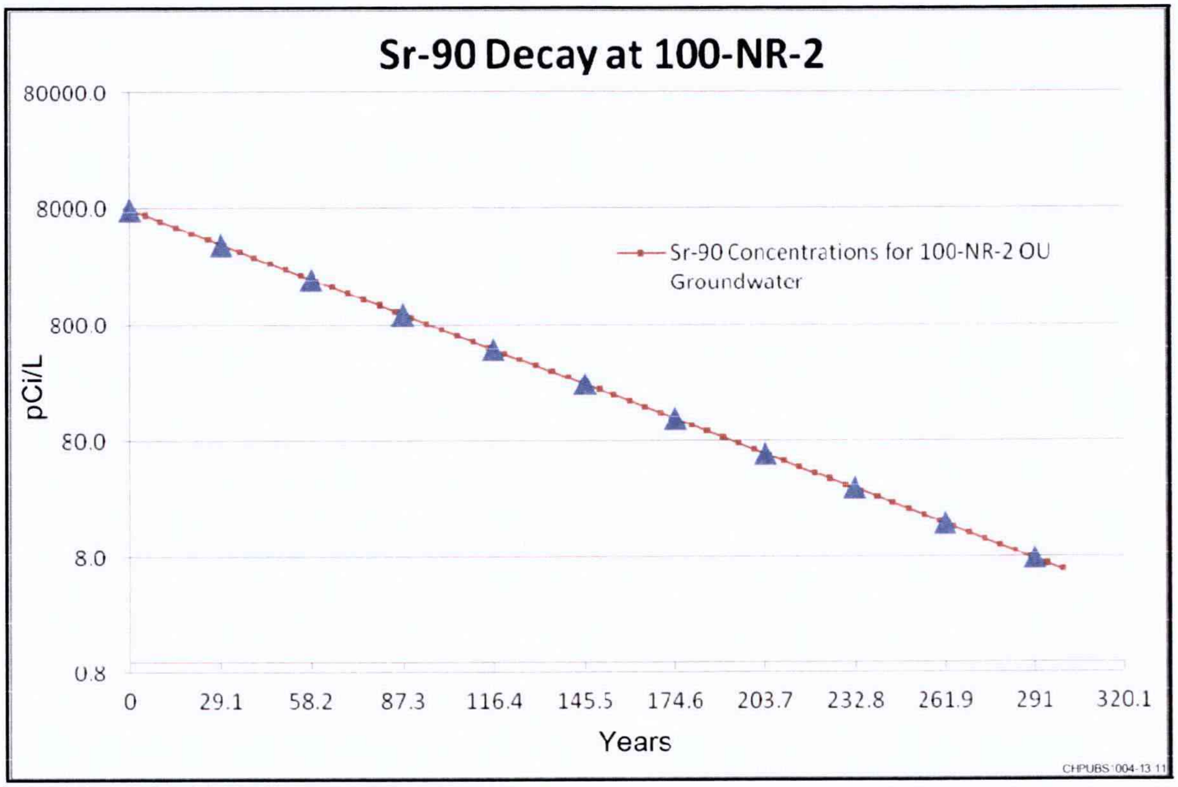


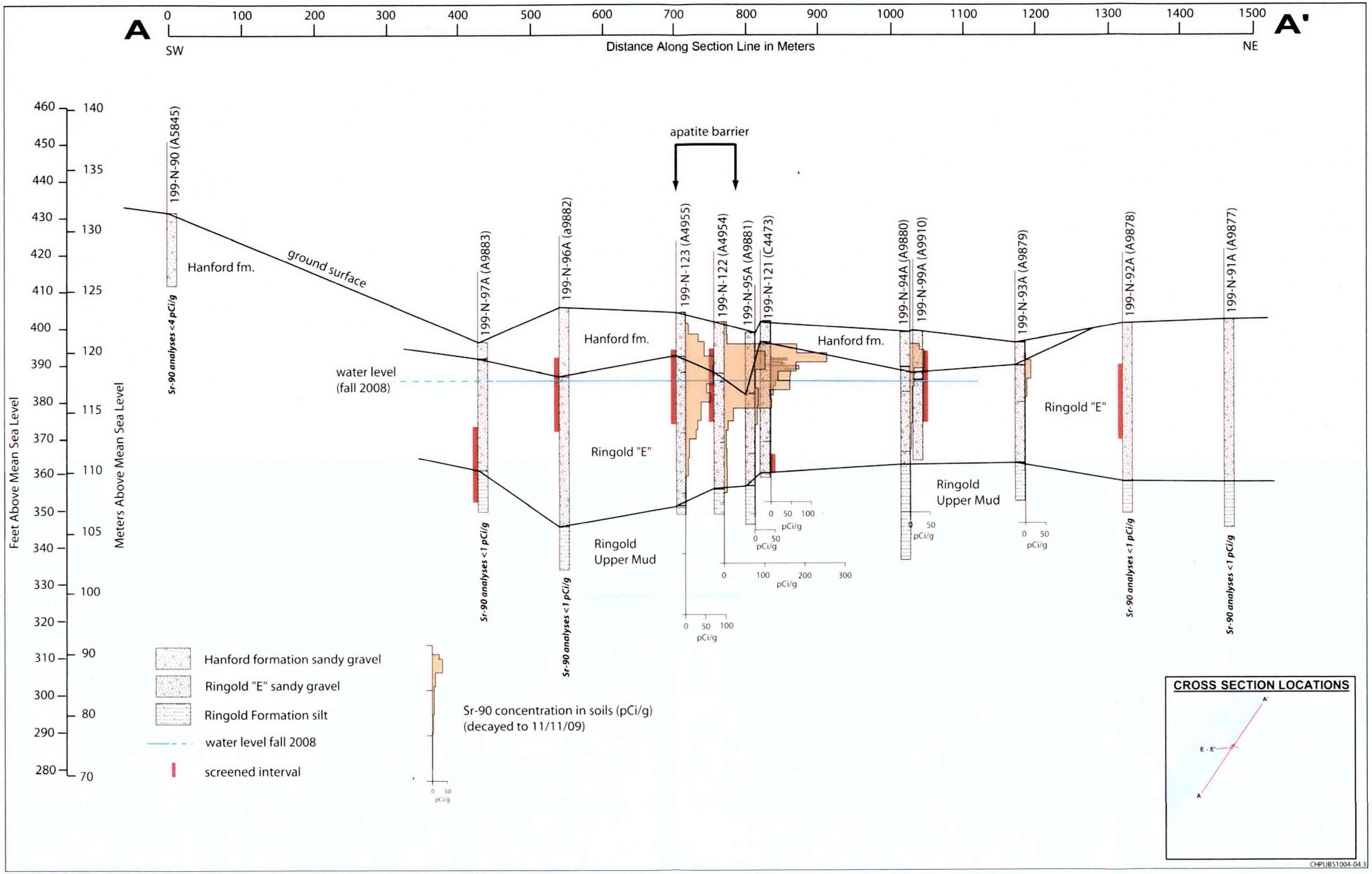
Figure 1-7. Strontium-90 Decay at 100-NR-2

Soil data have been collected from wells and borings within and around the former 1301-N and 1325-N LWDFs, as well as along the Columbia River shoreline (Figure 1-8). A majority of the strontium-90 bound to the soil in the unexcavated portion of the vadose zone underlying the former LWDFs is concentrated within a layer (approximately 3 m [10 ft] thick) around the current water table (Figure 1-8), at depths between 3 and 6.1 m (10 and 20 ft). Strontium-90 concentrations in soil from wells/borings near the LWDFs show concentrations decreasing with distance from the LWDFs and with depth (PNNL-18303). The majority of the strontium-90 contamination within the LWDFs was retained within the facilities (closer to the head end of the trench and immediately below the base). The LWDFs were excavated in 2005, and the contaminated concrete and soil were removed to a depth of 4.6 m (15 ft). The excavations were backfilled in 2006 (DOE/RL-2006-76, *Calendar Year 2006 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*).

Strontium-90 concentrations in soil samples collected from the wells/borings farther from the former LWDFs along the 100-N shoreline indicate that the majority of strontium-90 is located in the top of Ringold Formation unit E and the bottom of the Hanford formation. The water table near the Columbia River is located in the top of the Ringold Formation during low river level conditions (July through March), but the water table can rise up into the Hanford formation when river levels rise during Spring (late March to June) runoff periods. The majority of the contamination in soil along the Columbia River is in the immediate vicinity of the current apatite PRB, between Wells 199-N-123 to 199-N-121 (PNNL-16894, *Investigation of the Strontium-90 Contaminant Plume along the Shoreline of the Columbia River at the 100-N Area of the Hanford Site*).

Other contaminants currently monitored in wells and aquifer tubes within the 100-NR-2 OU include nitrate, tritium, sulfate, total petroleum hydrocarbons, manganese, iron, and chromium. Nitrate[3] concentrations greater than the 45 mg/L drinking water standards (DWSs) have been observed in groundwater samples collected from monitoring wells located near the 1301-N and 1325-N LWDFs, 120-N-1 Percolation Pond, and 120-N-2 Surface Impoundment. Tritium, sulfate, petroleum hydrocarbons, manganese, iron, and chromium present in groundwater at concentrations greater than their primary or secondary DWSs generally occur in much smaller areas. Petroleum hydrocarbons, iron, and manganese have been detected in several monitoring wells near the river shoreline. Chromium above the DWS has been found in only one well, completed in a water-bearing unit of the Ringold upper mud. The chromium detected in this well is most likely caused by the known stainless steel corrosion, which is occurring along the length of the well screen (DOE/RL-2010-11). Final RAs to address other groundwater contaminants, and the separate strontium-90 plume located near the outfall, will be evaluated in the RI/FS Report and Proposed Plan scheduled for completion in 2012.

[3] The DWS for nitrate is 45 mg/L, and nitrate expressed as nitrate-nitrogen is 10 mg/L.



Source: DOE/RL-2010-29

Figure 1-8. Strontium-90 Vertical Concentration Profiles for the 100-NR-1/NR-2 Operable Units

2 Basis for Remedial Action

This chapter presents a brief description of the amended interim action remedy and presents the basis for the RD, including the remedial action objectives (RAOs) identified in the Interim Action ROD Amendment.

2.1 Selected Remedy

The interim RA (selected remedy) for the 100-NR-2 OU described in the Interim Action ROD Amendment is designed to meet the RAOs outlined in Section 2.2. The remedy was selected based on the evaluation of alternatives conducted in DOE/RL-2009-54, *Proposed Plan for Amendment of 100-NR-1/NR-2 Interim Action Record of Decision*, and following a review of public comments received on the preferred alternative identified in DOE/RL-2009-54.

The selected interim action remedy for strontium-90 in the 100-NR-2 OU includes the following components:

- Extending the length of the existing apatite PRB from 90 m (300 ft) to a total length of approximately 760 m (2,500 ft) (in both the saturated and vadose zones).
- Additional apatite injections at a subset of injection well locations, within 5 years of completion of all first round apatite injections, as necessary to achieve a 90 percent reduction in the flux of strontium-90 to the river to support attainment of the 8 pCi/L RAG in the hyporheic zone by the year 2016. If the strontium-90 RAG is not achieved following the additional injections and implementation of any final RA deemed necessary in the final ROD, and an additional response is deemed necessary after the five-year period, the Tri-Parties will propose alternative actions to be taken.
- Decommissioning of the existing 100-NR-2 groundwater pump-and-treat system components including the treatment building, ion exchange (IX) vessels and hardware, and aboveground conveyance pipelines.
- MNA (of strontium-90).
- Maintaining the existing ICs and the riprap cover along the shoreline.
- Periodic groundwater monitoring to assess the effectiveness of the apatite PRB.

In addition to these elements, the following other components of the interim action selected in the 1999 Interim Action ROD will also continue:

- Maintaining the groundwater monitoring well network to further define the distribution of other COC plumes including: tritium, chromium, manganese, nitrate, sulfate, and total petroleum hydrocarbons
- Removing petroleum hydrocarbons from monitor wells if visible free product is observed during groundwater monitoring

Additional information on each of these elements is presented in the following subsections.

2.1.1 Apatite Permeable Reactive Barrier Extension and Supplemental Injections

A PRB is a subsurface treatment zone that immobilizes or transforms target contaminants as they are transported by natural groundwater flow through a reactive media. The extended apatite PRB to be constructed in the 100-NR-2 OU will consist of injecting apatite forming minerals, or preformed apatite, into the subsurface in a liquid or powder form. The reactive media, apatite, is a natural calcium phosphate mineral occurring in the earth's crust as phosphate rock. The apatite PRB immobilizes strontium-90 in vadose zone soil, aquifer solids, and groundwater by sequestering the strontium into the apatite's molecular structure via calcium substitution.

The apatite PRB will initially be extended 90 m (300 ft) to the southwest and 90 m (300 ft) to the northeast. This initial phase of the build-out will be performed as described in DOE/RL-2010-29, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit.* Information and experience gained from this work will be used to optimize the injection design and apatite solution composition for the full-scale build-out of the apatite PRB (Figure 2-1) to its 760 m (2,500 ft) length. In addition, the existing PRB will be extended into the overlying vadose zone. Vadose zone emplacement will use a jet injection delivery method.

If deemed necessary based on the results of future performance monitoring, an additional round of injections will be performed at a subset of injection well locations within five years of completing all apatite injection work. The need for and scope of any future injections will be identified in future Hanford Site groundwater monitoring and performance reports.

2.1.2 Decommissioning of the Pump-and-Treat System

Concurrent or following construction of the extended apatite PRB, DOE will decommission the treatment components of the existing 100-NR-2 OU groundwater pump-and-treat system. The decommissioning work will include removal of any residual IX media and disposal of this material at ERDF, dismantling all noncontact treatment system hardware and salvaging re-usable components, and cutting the high density polyethylene conveyance piping into short lengths for transportation and disposal at ERDF. Wells will remain in place and will be reconfigured for monitoring purposes. A summary of the decommissioning work will be provided in a future Hanford Site groundwater monitoring and performance report or interim action status report.

2.1.3 Groundwater Monitoring Program

Groundwater monitoring will be conducted to assess apatite PRB performance, and to track contaminant concentration changes in 100-NR-2 OU groundwater to develop information for use in selecting a final remedy for all COCs in accordance with DOE/RL-2009-42 and DOE/RL-2009-58.

Following completion of the apatite PRB performance monitoring to be conducted under DOE/RL-2010-29, it is expected that the monitoring program will be optimized as the apatite PRB is extended to its full 760 m (2,500 ft) length. An updated version of the performance monitoring program presented in Chapter 3 of this RD/RAWP (Rev. 1) will be presented in a future revision to DOE/RL-2009-58.

2.1.3.1 Monitored Natural Attenuation

MNA is also an important component of the selected remedy for strontium-90. MNA is the reliance on natural processes, within the context of a carefully controlled and monitored cleanup, to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in affected media. A majority of the strontium-90 present in the aquifer will naturally attenuate through radioactive decay (Figure 1-7) before it reaches the river, especially in the upland portions of the 100-N aquifer. MNA requires periodic sampling to verify that contaminant concentrations are declining in accordance with expectations and to ensure that contaminants remain isolated from potential points of exposure. Groundwater monitoring to be performed under DOE/RL-2008-46-ADD5 and DOE/RL-2009-58 will provide the data necessary to assess MNA effectiveness in the 100-NR-2 OU.

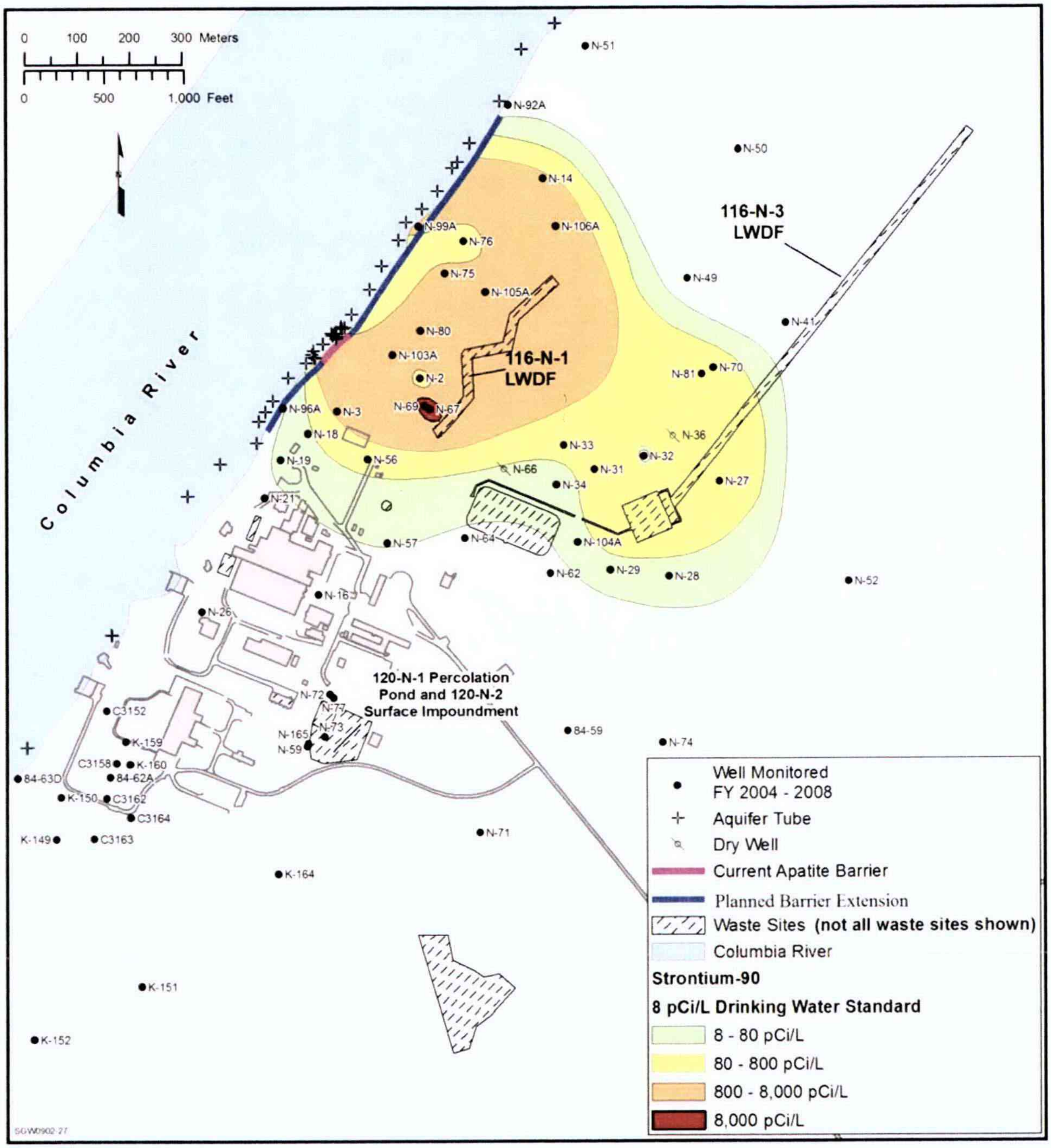


Figure 2-1. Apatite Permeable Reactive Barrier Location

The near-term results from this monitoring work will be presented in the RI/FS report scheduled for completion in 2012. Long-term monitoring results will be presented in future Hanford Site groundwater monitoring and performance reports.

2.1.4 Free Phase Petroleum Hydrocarbon Removal

The 1999 Interim Action ROD requires that free phase hydrocarbon product observed in any 100-N monitoring will be remediated. This element of the interim action currently consists of removing free product (diesel) from Well 199-N-18. If observed in other wells in the future, this action would also apply. The passive remediation approach involves the use of a polymer Smart Sponge that selectively absorbs petroleum products off the surface of water. Every two months, two of the sponges are lowered down, just into the water table, in Well 199-N-18. The sponges are weighed prior to emplacement in the well and during removal from the well. The difference in weight between the two measurements is the amount of product or diesel fuel contamination removed from the well. The results from this interim action will be presented in future Hanford Site groundwater monitoring and performance reports.

2.1.5 Institutional Controls

The remedy selected in the Interim Action ROD requires maintenance of ICs. The following ICs are required as part of the 100-NR-2 OU Interim Action ROD Amendment:

- DOE will continue to use a badging program and control access to the sites associated with this (amended interim action) ROD for the duration of the interim action. Visitors entering any of the sites associated with this Interim Action ROD Amendment are required to be escorted at all times.
- DOE will utilize the onsite excavation permit process to control land use, well drilling, and excavation of soil within the 100 Area OUs to prohibit any drilling or excavation except as approved by Ecology.
- DOE will maintain existing signs prohibiting public access.
- Trespass incidents will be reported to the Benton County Sheriff's Office for investigation and evaluation for possible prosecution.
- DOE will provide notification to Ecology upon discovery of any trespass incidents.
- DOE will take the necessary precautions to add access restriction language to any land transfer, sale, or lease of property that the U.S. Government considers appropriate while ICs are compulsory, and Ecology will have to approve any access restrictions prior to transfer, sale, or lease.
- Until final remedy selection, DOE shall not delete or terminate any IC requirement established in this Interim Action ROD Amendment unless Ecology has provided written concurrence on the deletion or termination and appropriate documentation has been placed in the Administrative Record (AR).

DOE will evaluate the implementation and effectiveness of ICs for the 100-NR-1 and 100-NR-2 OUs on an annual basis. DOE shall submit a report to Ecology by July 31 of each year summarizing the results of the evaluation for the preceding calendar year. At a minimum, the report shall contain an evaluation of whether or not the IC requirements continue to be met and a description of any deficiencies discovered and measures taken to correct problems. Additional information on ICs is provided in DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*.

2.1.6 Maintain Riprap Cover

DOE will maintain the existing riprap cover that was placed over the historic groundwater seeps and springs along the shoreline. This will consist of periodic visual monitoring of the riprap cover along the shoreline and replacement of any cover material that is eroded. Any maintenance performed will be described in future Hanford Site groundwater monitoring and performance reports.

2.2 Remedial Action Objectives

RAOs are narrative statements that define the extent to which the OU requires cleanup to protect HHE. The Interim Action ROD specifically defines four RAOs, as follows:

- Protect the Columbia River from adverse impacts from the 100-NR-2 groundwater so designated beneficial uses of the river are maintained. Protect potential human and ecological receptors using the river from exposure to radioactive and nonradioactive contaminants present in the unconfined aquifer. Protection will be achieved by limiting exposure pathways, reducing or removing contaminant sources, controlling groundwater movement, or reducing concentrations of contaminants in the unconfined aquifer.
- Protect the unconfined aquifer by implementing RAs that reduce concentrations of radioactive and nonradioactive contaminants present in the unconfined aquifer.
- Obtain information to evaluate technologies for strontium-90 removal and evaluate ecological receptor impacts from contaminated groundwater. (This objective was achieved with issuance of *Evaluation of Strontium-90 Treatment Technologies for the 100-NR-2 Groundwater Operable Unit Letter Report* [Fluor Hanford and CH2M HILL, 2004] and DOE/RL-2006-26, *Aquatic and Riparian Receptor Impact Information for the 100-NR-2 Groundwater Operable Unit.*)
- Prevent destruction of sensitive wildlife habitat. Minimize the disruption of cultural resources and wildlife habitat in general and prevent adverse impacts to cultural resources and threatened or endangered species.

2.3 Remedial Action Goals

RAGs are contaminant specific numerical cleanup criteria developed to ensure that the RAs meet the RAOs set forth in the Interim Action ROD Amendment.

A RAG of 8 pCi/L was established in the Interim Action ROD as the allowable concentration of strontium-90 in groundwater and surface water that is protective of HHE. The RAG for strontium-90 corresponds to the 8 pCi/L federal DWS based on a 4 millirem per year annual dose. There is no federal or state ambient water quality standard for strontium-90. Therefore, the Tri-Parties agreed to adopt the DWS as the RAG for strontium-90 in surface water.

2.4 Applicable or Relevant and Appropriate Requirement Compliance

This section discusses the applicable or relevant and appropriate requirements (ARARs) identified in the 1999 Interim Action ROD. The Interim Action ROD includes a combined list of ARARs for both the surface waste sites (100-NR-1 OU) and for the groundwater (100-NR-2 OU). Some of the ARARs listed are primarily applicable to the surface waste sites within the 100-NR-1 OU and do not necessarily apply to the groundwater interim RAs.

The "National Oil and Hazardous Substances Contingency Plan" (NCP) (40 CFR 300) and the Interim Action ROD Amendment require RAs to comply with federal and state ARARs as established in the Interim Action ROD. All activities associated with the RAs covered under the Interim Action ROD will take place onsite, as defined in the NCP. Therefore, the RAs need only meet the substantive requirements of the ARARs established in the Interim Action ROD.

As detailed planning documents are prepared for the amended interim RA, compliance with ARARs will be evaluated. This section may be revised as necessary to incorporate any new activities that are subject to the ARARs. If a new ARAR (under WAC 173-340, *Model Toxics Control Act* [MTCA]—*Cleanup*, for example) is promulgated, the requirement will be reviewed by DOE to determine if the interim RA is still protective based on the new requirement. This determination will be documented by the Tri-Parties in the AR.

2.4.1 Chemical Specific Applicable or Relevant and Appropriate Requirements

Chemical specific ARARs are typically health or risk based numerical regulatory values or methodologies applied to site-specific media and are used to establish cleanup criteria.

The chemical specific ARARs identified in the Interim Action ROD are as follows:

- "Hazardous Waste Cleanup—Model Toxics Control Act" (RCW 70.105D) and "Model Toxics Control Act—Cleanup" (WAC 173-340).
- *Safe Drinking Water Act of 1974*, "National Primary Drinking Water Regulations" (40 CFR 141), and "National Secondary Drinking Water Regulations" (40 CFR 143). A partial exemption to this ARAR was granted in the Interim Action ROD to provide for re-injection of treated groundwater with strontium-90 concentrations above the 8 pCi/L DWS. Currently, there are no promulgated DWS for apatite forming minerals (calcium citrate and sodium phosphate).
- *Federal Water Pollution Control Act of 1977* (RCW 90.48) and "Water Quality Standards" (40 CFR 131).
- "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A).

An interim action waiver for some of these ARARs was granted for the pump-and-treat system, on the basis that the interim action will be followed by a final action that will meet all ARARs.

Washington State's MTCA regulation establishes numerical concentration values and methodologies used for deriving cleanup goals. The regulation includes requirements that cleanup of, and residual contamination remaining in, one site medium (e.g., soils and groundwater) does not impact other media, either onsite or offsite (WAC 173-340-700 (4)(b) and (7)(h)). These requirements were considered in the cleanup criteria for the selected interim RA. In addition to the cleanup criteria contained in MTCA, the *Federal Water Pollution Control Act* and the "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A) define the criteria that must be met to demonstrate that the contaminated groundwater from the 100-NR-2 OU is not impacting the Columbia River. Implementation of the selected interim RAs will help achieve chemical specific ARARs for strontium-90 in groundwater and surface water at 100-N.

2.4.2 Action Specific Applicable or Relevant and Appropriate Requirements

Action specific ARARs typically are technology or activity based regulatory requirements or limitations triggered by a particular action (e.g., well drilling or waste handling).

Activities associated with the 100-NR-2 OU interim RA that generate waste will comply with the substantive requirements in the action specific waste management ARARs identified in this section and in the Interim Action ROD. The primary waste that will be produced during the 100-NR-2 amended interim RA is waste material associated with decommissioning of the pump-and-treat system, un-used apatite forming chemicals and preformed apatite, drill cuttings, purge/pore water, and miscellaneous nonhazardous solid waste. The Interim Action ROD provides the necessary regulatory authority to dispose of this material at ERDF after it has been treated (as necessary) in accordance with WCH-191, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*. This document specifies application of the waste management ARARs for any waste disposed at ERDF, including the following:

- "Hazardous Waste Management" (RCW 70.105)
- "Dangerous Waste Regulations" (WAC 173-303)

- "Land Disposal Restrictions" (40 CFR 268)
- "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Miscellaneous Units" (40 CFR 264, Subpart X)
- "Solid Waste Management—Reduction and Recycling" (RCW 70.95) and "Minimum Functional Standards for Solid Waste Handling" (WAC 173-304)
- *Toxic Substances Control Act of 1976* (implemented via "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions" [40 CFR 761])
- "Criteria and Procedures for Emergency Access to Non-Federal and Regional Low-Level Waste Disposal Facilities" (10 CFR 62)

Other interim RA ARARs include the following:

- "State Waste Discharge Permit Program" (WAC 173-216).
- "Underground Injection Control Program" (WAC 173-218). An exemption to this ARAR was granted in the Interim Action ROD to provide for re-injection of treated groundwater with strontium-90 concentrations above the 8 pCi/L DWS. A continuation of this exemption is necessary to provide for injection of apatite forming minerals.

The WAC 173-216 regulation is a substantive (nonpermitting) requirement applicable to remedial activities that result in any liquid discharge to the ground, including requirements for all known available and reasonable methods of prevention, control, and treatment and discharge limits. Routine liquid discharges to the ground surface are not anticipated as part of the amended interim RA. However, discharge of un-used apatite forming minerals and preformed apatite may occur as a supplement to vadose zone emplacement. Discharges to the groundwater are addressed in WAC 173-218.

The WAC 173-218 regulation is a substantive (nonpermitting) requirement applicable to remedial alternatives that discharge liquid through wells that may endanger groundwater of the state. Apatite forming chemicals will be injected into the aquifer as part of the amended interim RA. These chemicals will react to form solid phase apatite. Unreacted chemical residuals are not expected to migrate beyond the treatment zone. The effects of unreacted chemicals, transported to the river by groundwater, on threatened and endangered species are described in PNNL-SA-75348.

The following action specific ARARs are listed in the Interim Action ROD:

- *Clean Air Act of 1977* and 40 CFR 61, "National Emissions Standards for Hazardous Air Pollutants"
- "Washington Clean Air Act" (RCW70.94) and "General Regulations for Air Pollution Sources" (WAC 173-400)
- "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480)
- "Nuclear Energy and Radiation" (RCW 70.98) and "Radiation Protection – Air Emissions" (WAC 246-247)
- "Minimum Standards for Construction and Maintenance of Wells" (WAC 173-160)

The radionuclide air emission standards ("National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" [40 CFR 61, Subpart H]; WAC 173-480; and

WAC 246-247) are not expected to apply to the selected interim RA as all treatment is performed in situ. There is no ex situ treatment that would generate air emissions.

WAC 173-400 establishes requirements for emissions of nonradioactive air pollutants. Nonradioactive co-contaminants (e.g., chromium, manganese, nitrate, sulfate, and petroleum hydrocarbons) are present in low concentrations, mostly below DWSs. Because of the low concentrations and the nature of the remediation activities being performed, actual emissions of nonradioactive contaminants are not anticipated. Therefore, this regulation is not considered applicable for this interim RA.

Standards for the construction, operation, and abandonment of resource protection (i.e., monitoring and injection) wells are specified in WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells." All new wells required under the interim RA will be constructed in accordance with these standards or as allowed by an Ecology approved variance.

2.4.3 Location Specific Applicable or Relevant and Appropriate Requirements

Location specific ARARs are restrictions placed on hazardous substance concentrations or RAs based on the specific location of the substance or action. The location specific ARARs established in the Interim Action ROD include the following:

- *Archeological and Historical Preservation Act of 1974* (implemented via 36 CFR 65, "National Historic Landmarks Program")
- *Archeological Resources Protection Act of 1979* (implemented via 43 CFR 7, "Native American Graves Protection and Repatriation Regulations," "Protection of Archaeological Resources")
- *National Historic Preservation Act of 1966* (implemented via 36 CFR 800, "Protection of Historic Properties")
- *Migratory Bird Treaty Act of 1918* (implemented via 16 USC 703)
- *Endangered Species Act of 1973* (implemented via 50 CFR 17, "Endangered and Threatened Wildlife and Plants," 50 CFR 22, "Eagle Permits";50 CFR 25, , "Administrative Provisions"; 50 CFR 226, "Designated Critical Habitat"; 50 CFR 402, "Interagency Cooperation—Endangered Species Act of 1973, as Amended"; and 50 CFR 424, "Listing Endangered and Threatened Species and Designating Critical Habitat")
- "Habitat Buffer Zone for Bald Eagle Rules" (RCW 77.12.655,"Powers and Duties," "Habitat Buffer Zone for Bald Eagle—Rules") (implemented via WAC 232-12-292, "Permanent Regulations," "Bald Eagle Protection Rules")
- *Hanford Reach Study Act* (Public Law 100-605)

The *Archeological and Historical Preservation Act of 1974* is applicable when remedial activities may cause irreparable harm, loss, or destruction of significant artifacts in the 100-N area. The *Archaeological and Historical Preservation Act of 1974* requires that RAs at the source area sites do not cause the loss of archaeological or historic data and that any archaeological or historic data must be preserved. If any archaeological or historical artifacts are encountered during implementation of the interim RA, the appropriate authorities will be notified and the artifacts will be preserved in accordance with DOE/RL-98-10, *Hanford Cultural Resources Management Plan.*

The *Archeological Resources Protection Act of 1979* is applicable when remedial activities may cause possible harm or destruction of sites in the 100-N area having religious or cultural significance. If any archaeological or historical artifacts are encountered during implementation of the interim RA, the appropriate authorities will be notified and the artifacts will be preserved in accordance with DOE/RL-98-10.

The *National Historic Preservation Act of 1966* requires that agencies undertaking projects must evaluate impacts to properties listed, or eligible for inclusion, on the National Register of Historic Places. Consideration of historically significant properties will be evaluated if the interim RA needs to be extended beyond the currently defined alignment.

The *Migratory Bird Treaty Act of 1918* was implemented in the 1916 Convention between the United States and Great Britain (for Canada) for the protection of migratory birds. Later amendments implemented treaties between the United States and Mexico, the United States and Japan, and the United States and the Soviet Union (now Russia). Public Law 95-616 also ratified a treaty with the Soviet Union specifying that both nations will protect ecosystems of special importance to migratory birds against pollution, detrimental alterations, and other environmental degradations. Implementation of the selected interim RA is not expected to impact migratory bird ecosystems.

The *Endangered Species Act of 1973* requires that federal agencies consult with the Department of Interior, National Marine Fisheries Service, and other appropriate agencies to ensure that actions authorized, funded, or implemented do not jeopardize the continued existence of endangered or threatened species or adversely affect their critical habitat. Because several listed and candidate endangered or threatened species have been identified in and around the Hanford Site, the interim RA described in this document will be managed so these species neither will be jeopardized, nor will their habitat be adversely affected.

RCW 77.12.655 and WAC 232-12-292 are applicable if the areas of remedial activities include bald eagle habitat. The interim RA will comply with this ARAR..

The *Hanford Reach Study Act* is applicable to remedial activities that could result in any direct and adverse impacts to the Columbia River. Consultation with the U.S. National Park Service is required. The interim RA is designed to protect the Columbia River from any adverse impacts, therefore achieving compliance with this ARAR.

2.4.4 Other Criteria, Advisories, or Guidance to Be Considered

Information to be considered generally consists of federal, state, and local criteria, advisories, and proposed standards that are not legally binding (i.e., are not promulgated regulations) but that may be useful in establishing cleanup goals or remedial alternatives that are protective of HHE. The information to be considered was identified in the Interim Action ROD and includes the following:

- **Environmental Restoration Disposal Facility Waste Acceptance Criteria.** Waste acceptance criteria (e.g., concentration limits and waste form limitations) have been developed for ERDF (*Environmental Restoration Disposal Facility Waste Acceptance Criteria* [BHI-00139]). The ERDF waste acceptance criteria provide the primary requirements that must be met for waste to be accepted for disposal at ERDF. It also cites specific regulations to direct the user to the level of detail necessary for criteria implementation.

- **Hanford Future Site Uses Working Group.** The Hanford Future Site Uses Working Group provided recommendations for future uses of the land on the Hanford Site in *The Future for Hanford: Uses and Cleanup, the Final Report of the Hanford Future Site Uses Working Group* (Drummond, 1992). The RAOs included in the Interim Action ROD are based on the recommendations identified in the working group's report.

- **DOE/EIS-0222-F, *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement.*** The *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement* evaluates the potential environmental impacts associated with implementing a comprehensive land-use plan for the Hanford Site for at least the next 50 years. With the exception of the required no-action alternative, each of the six alternatives presented represents a Tribal, federal, state, or local agency's preferred alternative. DOE's preferred alternative anticipates multiple uses of the Hanford Site, including consolidating waste management operations in the Central Plateau, allowing industrial development in the eastern and southern portions of the Hanford Site, increasing recreational access to the Columbia River, and expanding the Saddle Mountain National Wildlife Refuge to include all of the Wahluke Slope and Fitzner Eberhardt Arid Lands Ecology Reserve (managed by the U.S. Fish and Wildlife Service). In DOE/EIS-0222-SA-01, *Supplement Analysis: Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, DOE found no significant new circumstances or changes relevant to environmental concerns that affect the comprehensive land-use plan. DOE concluded that using the regulatory processes in place at the Hanford Site under the framework of the TPA is an acceptable way to ensure land use is being implemented consistently with the comprehensive land use plan.

- **USFWS, 2008, *Hanford Reach National Monument: Final Comprehensive Conservation Plan and Environmental Impact Statement Adams, Benton, Grant and Franklin Counties, Washington.*** The *Hanford Reach National Monument Comprehensive Conservation Plan* (CCP) provides direction to the United States Fish and Wildlife Service and DOE on management of the Hanford Reach National Monument (Monument) for the next 15 years (through 2023). The CCP provided the framework for making decisions on conserving natural, cultural, and recreational resources; managing visitor use; developing facilities; and addressing day-to-day operations of the Monument. The CCP will ensure that future opportunities are realized and problems addressed effectively.

3 Remedial Design Approach

This chapter provides RD information and a description of RA activities necessary to support implementation of the selected remedy. The RD and RAs required by the Interim Action ROD Amendment are necessary to reduce the flux of strontium-90 to the Columbia River.

3.1 Design Basis

Efforts to reduce the flux of strontium-90 to the Columbia River from past-practice LWDFs have been underway in 100-N at the Hanford Site since the early 1990s. Termination of all liquid discharges to the vadose zone by 1993 was a major step toward meeting this goal. However, strontium-90 adsorbed on aquifer and periodically re-wetted zone solids beneath the LWDFs and extending to and beneath the near-shore riverbed remains as a continuing source to groundwater and the Columbia River.

The Interim Action ROD for the 100-NR-1/NR-2 OUs (EPA/ROD/R10-99/112) recognized the limitations of pump-and-treat technology for strontium-90 remediation by requiring that alternative treatment technologies be evaluated. The need for alternative technologies was affirmed in the first CERCLA five-year review, which re-emphasized the need to pursue alternative RA technologies aggressively for the removal, mass reduction, and/or attenuation of strontium-90 from the 100-NR-2 aquifer sediments and to provide further reduction of strontium-90 flux to the river (*U.S. DOE Hanford Site First Five Year Review Report* [EPA, 2001]). Additionally, the *Hanford Site Groundwater Monitoring for Fiscal Year 2006* (PNNL-16346) recognized from the onset that groundwater pump-and-treat was unlikely to be an effective long-term treatment method because of the geochemical characteristics of strontium-90. Subsequent performance monitoring confirmed this determination.

Following an evaluation of potential strontium-90 treatment technologies and their applicability under 100-NR-2 OU hydrogeologic conditions, the Tri-Parties agreed that the long-term strategy for groundwater remediation at 100-N should include apatite sequestration as the primary treatment technology (*The Second CERCLA Five-Year Review Report for the Hanford Site* [DOE/RL-2006-20]). This agreement was based on results from an evaluation of remedial alternatives that identified the apatite PRB technology as the approach showing the greatest promise for reducing strontium-90 flux to the Columbia River at a reasonable cost. The Interim Action ROD Amendment (EPA, 2010) replaces the strontium-90 groundwater pump-and-treat system with a subsurface apatite PRB.

Based on the information and experience gained from performance of the work, enhancements have been identified to improve the delivery and emplacement of apatite forming chemicals within the unconfined aquifer to produce an effective PRB. The design optimization study (DOS), DOE/RL-2010-29, was prepared to aid in the deployment and evaluation of these enhancements for the first 183 m (600 ft) extension. Once the performance of these enhancements has been demonstrated, full-scale build-out of the apatite PRB to 760 m (2,500 ft) will be performed.

The effectiveness of the apatite PRB will be assessed based on its ability to achieve a 90 percent reduction in strontium-90 flux to the river. With time, strontium-90 concentrations near the apatite PRB are expected to decrease as strontium-90 is incorporated into the apatite structure. The apatite PRB technology is expected to be an important component of the final remedy to address strontium-90 at 100-N.

3.2 Conceptual Design Approach

The following subsections present conceptual design information for the apatite PRB design to be deployed in the saturated and vadose zones.

3.2.1 Saturated Zone Permeable Reactive Barrier

The DOS for the apatite PRB will focus on the unconfined aquifer and the near-shore area capillary fringe in the 100-NR-2 OU. Field implementation will be accomplished through injection into multipurpose wells that were installed under DOE/RL-2009-32, *100-NR-2 Groundwater Operable Unit Strontium-90 Plume Rivershore Sampling and Analysis Plan.*

The DOS and related design elements include the following objectives:

1. Refine application of the high-concentration calcium-citrate-phosphate solution over a larger scale.

   Refine the application of the high-concentration calcium-citrate-phosphate solution through testing the well design, injection equipment, monitoring well sampling, and aquifer tube sampling for decreases in strontium concentrations and tracking transient effects of increased metals and anions.

2. Test the effectiveness of high concentration calcium-citrate-phosphate injection in previously untested sediment to compare with areas that received sequential injections of low- then high-concentration calcium-citrate-phosphate injections.

   The effectiveness will be demonstrated through long-term monitoring of wells and aquifer tubes for decreases in strontium concentrations and tracking transient effects of increased metals and anions.

3. Test the new well design installed under DOE/RL-2009-32 to evaluate the adequacy of injection solution delivery to the target zone.

   The new well design will be evaluated through monitoring of groundwater and aquifer tubes through collection of field conductivity measurements in conjunction with groundwater sampling for phosphate.

4. Test and optimize operation of the new injection system to verify that the system can deliver the designed injection solution flow volume at multiple well locations. Determine whether the new well design and injection system can complete chemical injections at various river stages, thereby eliminating the need for injections during specific river levels.

   This will be evaluated by performing injections independent of river stage and collecting field conductivity measurements in conjunction with groundwater sampling for phosphate to determine the treatment area achieved.

5. Evaluate if the PRB can achieve up to 90 percent reduction in strontium-90 flux to the river.

   This will be demonstrated through monitoring well and aquifer tube sampling for decreases in strontium concentrations and by tracking transient effects of increased metals and anions.

6. Further test the impact the high-concentration calcium-citrate-phosphate solution has on the release of strontium-90 and other metals from previously untreated sediments to groundwater.

   This will be demonstrated through monitoring well and aquifer tube sampling for decreases in strontium concentrations and tracking transient effects of increased metals and anions.

3.2.1.1 Well Installation

The wells needed for the apatite PRB extension include monitoring wells and multipurpose injection remediation/characterization wells. Along the length (760 m [2,500 ft]) of the apatite PRB, 146 multipurpose wells were constructed, and 25 monitoring wells installed at periodic intervals at locations downgradient of the multipurpose wells (DOE/RL-2009-32). Twenty-five existing monitoring wells are also located within the footprint of the current apatite PRB. To provide data about the effectiveness of the existing PRB, 3 of the 25 wells recently installed were continuously cored to total depth (TD). Based on the strontium-90 vertical profile sampling conducted during installation of the low-concentration pilot test wells, well screen intervals ranging in depth from 3.1 to 7.3 m (10 to 24 ft) below ground surface (bgs) were selected for the balance of the multipurpose wells installed as part of the overall barrier installation (PNNL-17429). The multipurpose wells were drilled along the shoreline road northeast and southwest of the current apatite PRB at 6 m (15 ft) intervals. Figure 3-1 shows the location of the existing apatite PRB area and its relation to the two areas of barrier expansion. Figure 3-2 shows the location of the new multipurpose and monitoring wells installed upstream of the existing barrier area, while Figures 3-3 to 3-5 show the location of the new multipurpose and monitoring wells located downstream of the existing barrier. Approximately half of the multipurpose wells are completed in the Hanford formation (shallow multipurpose wells). These wells alternate with multipurpose wells completed in the Ringold Formation E (deep multipurpose wells).

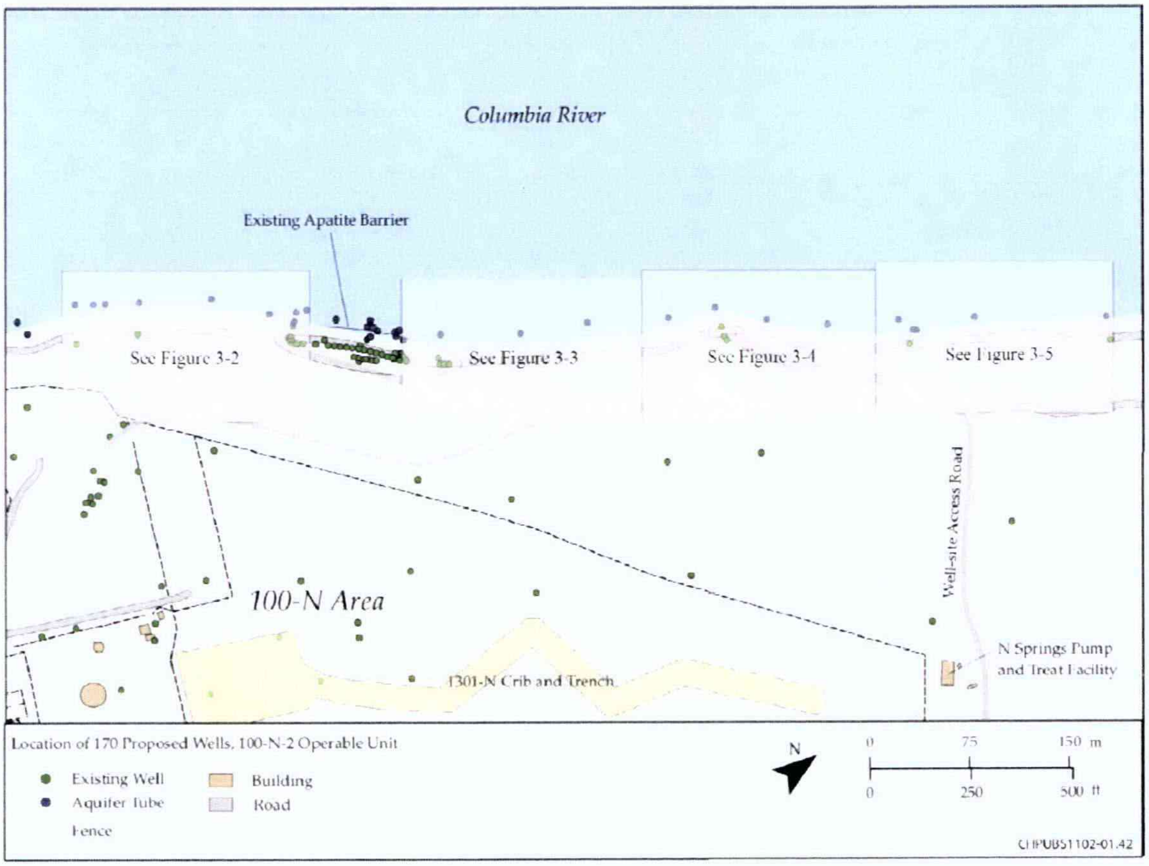


Figure 3-1. Injection Well Location Area

All wells were drilled with a 25 cm (10 in.) diameter temporary casing to allow construction of a 15 cm (6 in.) diameter multipurpose well (i.e., the boreholes were drilled to maintain a minimum 5 cm [2 in.] annular space around the permanent well, per WAC 173-160). Shallow multipurpose well boreholes were drilled to a TD of approximately 4.6 m (15 ft) bgs, and the deep multipurpose well boreholes were drilled to a TD of approximately 7.5 m (25 ft) bgs. The monitoring wells were drilled to a TD of 7.5 m (25 ft) bgs. Table 3-1 presents general construction details for the new apatite PRB deployment wells. Additional details on the borehole drilling and well construction details are presented in SGW-47791, *Borehole Summary for the Installation of One Hundred and Seventy One Wells at 100-NR-2 Operable Unit, FY 2009-2010*.

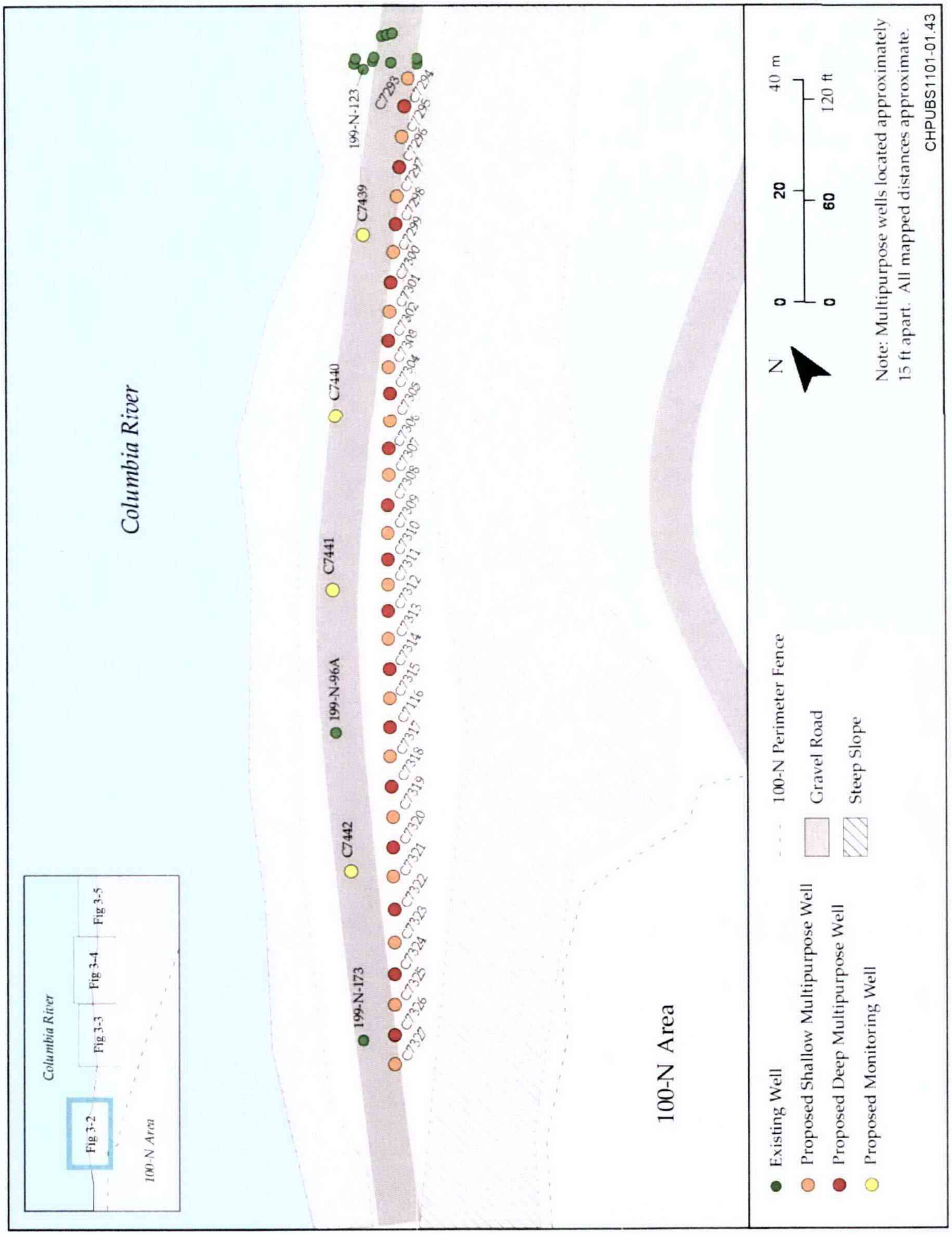


Figure 3-2. Well Locations—Upstream of Existing Permeable Reactive Barrier

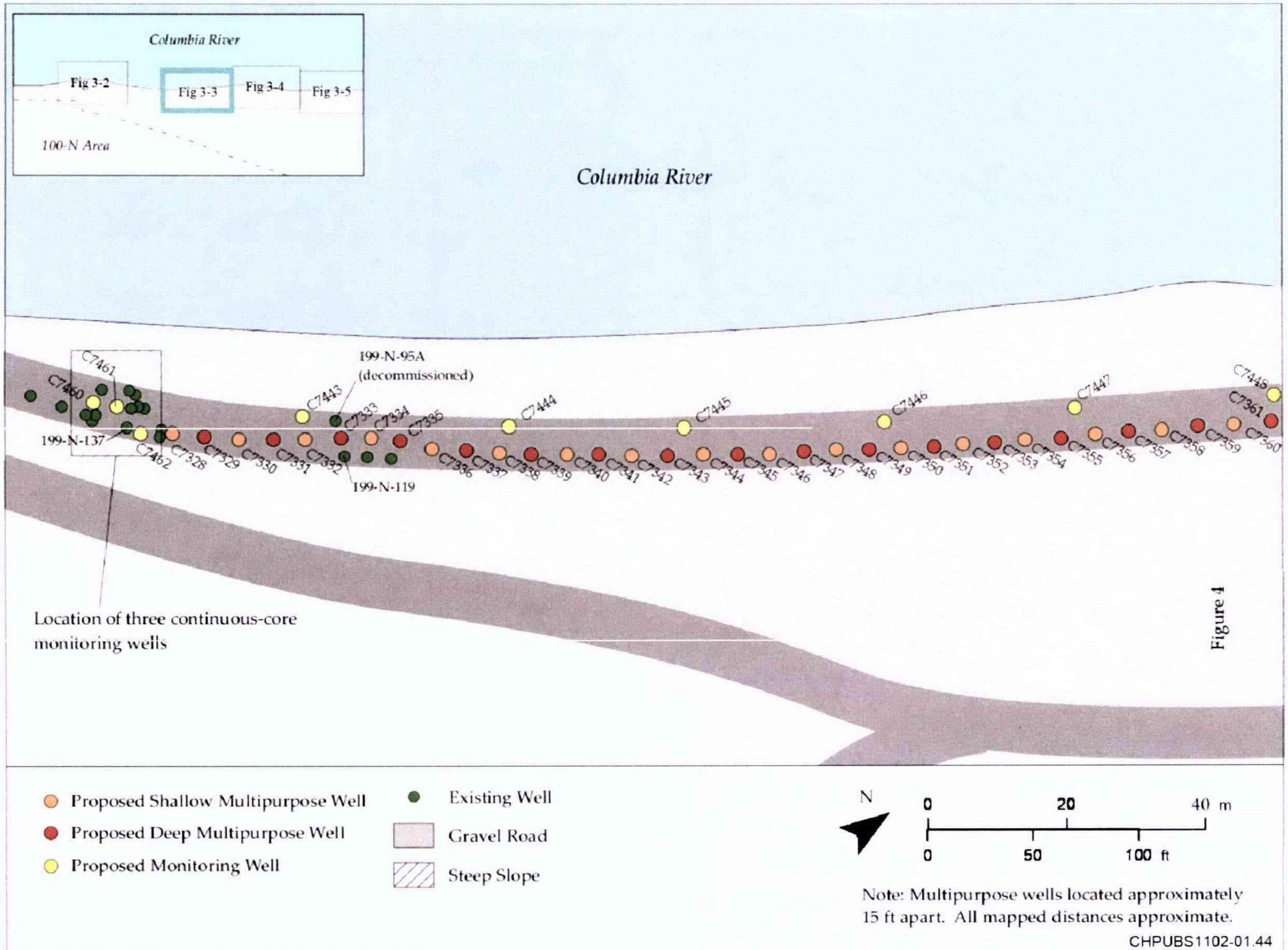


Figure 3-3. Well Locations—Downstream of Existing Permeable Reactive Barrier

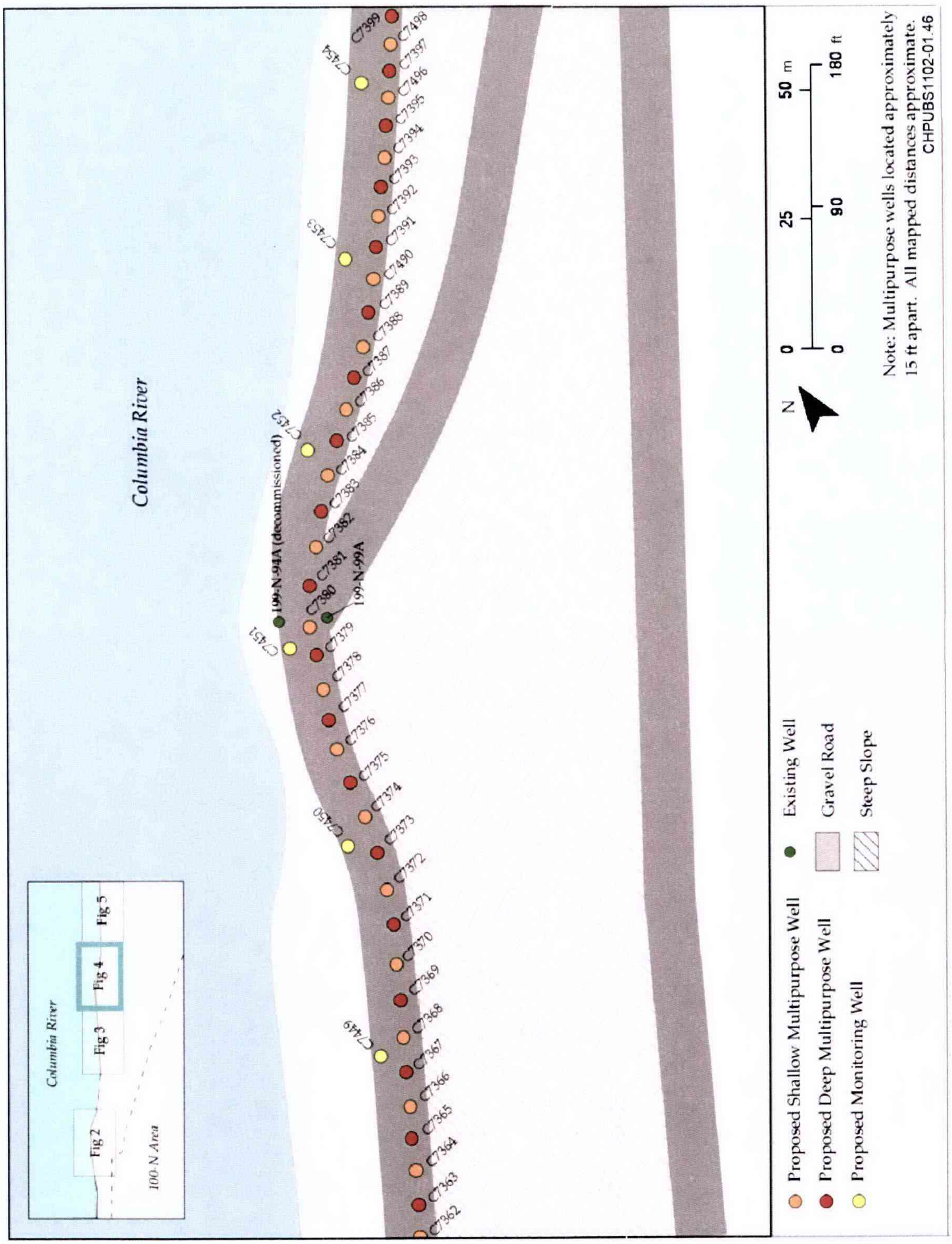


Figure 3-4. Well Locations—Downstream of Existing Permeable Reactive Barrier

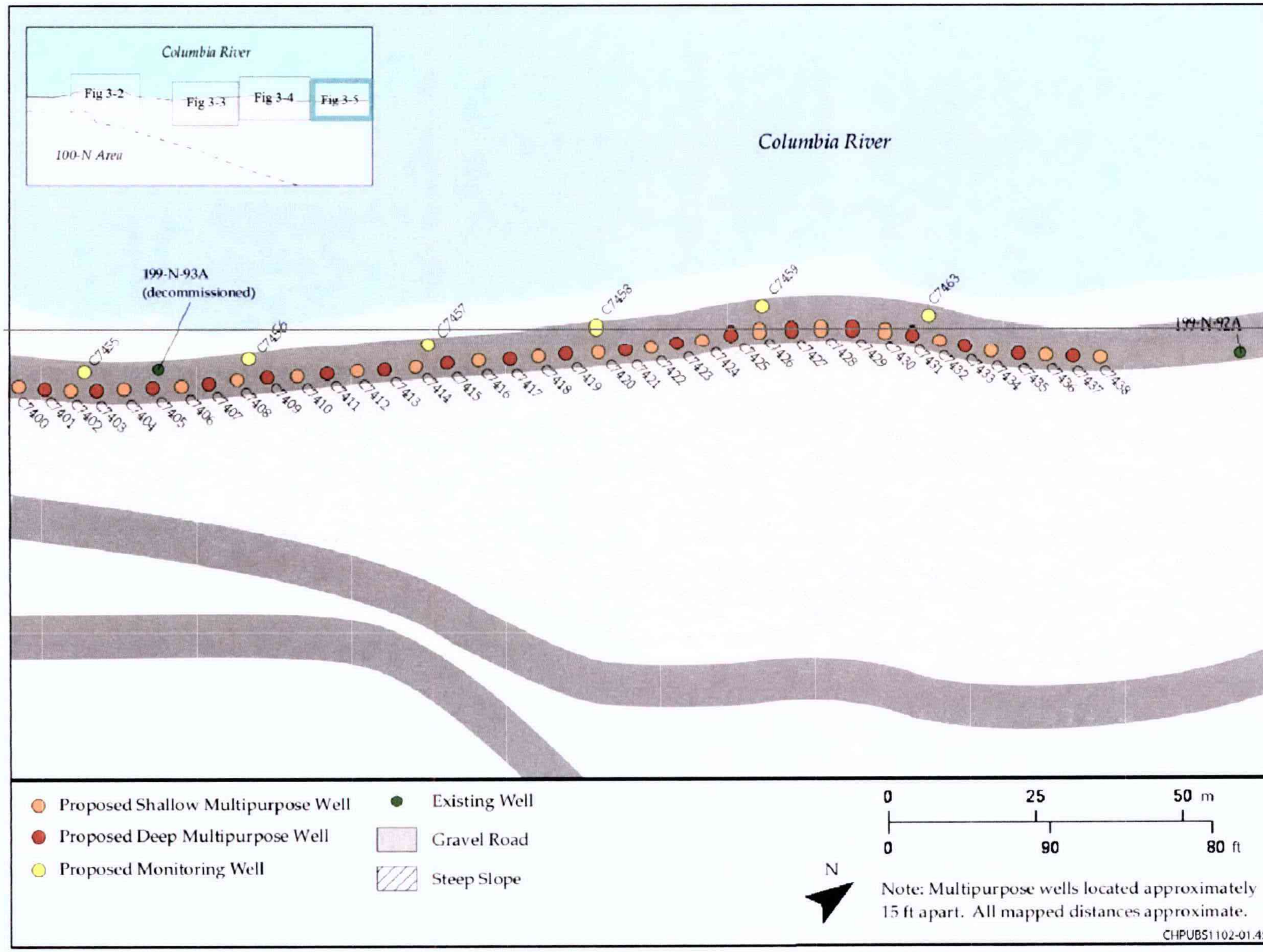


Figure 3-5. Well Locations—Downstream of Existing Permeable Reactive Barrier

Table 3-1. Typical Multipurpose Well Construction Details

Well Type	Planned Drill Depth (ft bgs)[a]	Estimated Depth to Water (ft bgs)[a]	Screen Length (ft)	Screen Placement (ft bgs)	Filter Pack Interval (ft bgs)[b]	Bentonite Pellet Interval (ft bgs)	Bentonite Crumbles Interval (ft bgs)	Cement Seal Interval (ft bgs)
Shallow Multipurpose (Hanford)	15	Dependent on river stage (expected between 8 and 17)	5	10 to 15	9 to 15	7 to 9	5 to 7	0 to 5
Deep Multipurpose (Ringold)	25	Dependent on river stage (expected between 8 and 17)	7	17 to 24	16 to 25	13 to 16	10 to 13	0 to10

Note: All wells have 15 cm (6 in.) diameter polyvinyl chloride casing and screen. Drill depth, screened interval, and bentonite seal intervals vary slightly due to location specific conditions.

a. Estimated planned drill depth and depth to water from DOE/RL-2009-32, *100-NR-2 Groundwater Operable Unit Sr-90 Plume Rivershore Sampling and Analysis Plan.*

b. Filter pack interval to consist of 6 to 9 mesh Colorado silica sand or equivalent.

Two new injection skids were designed (Figure 3-6) and constructed (Figure 3-7) to inject the aqueous solution of chemical and river water through the multipurpose wells. CH2M HILL Plateau Remediation Company (CHPRC) Soil and Groundwater Remediation Project engineering (licensed professional engineers) designed the new injection systems in accordance with their design procedures and standard design criteria. The new injection skids increase the coverage area and decrease the time required for each injection, allowing for injecting chemicals into six wells simultaneously.

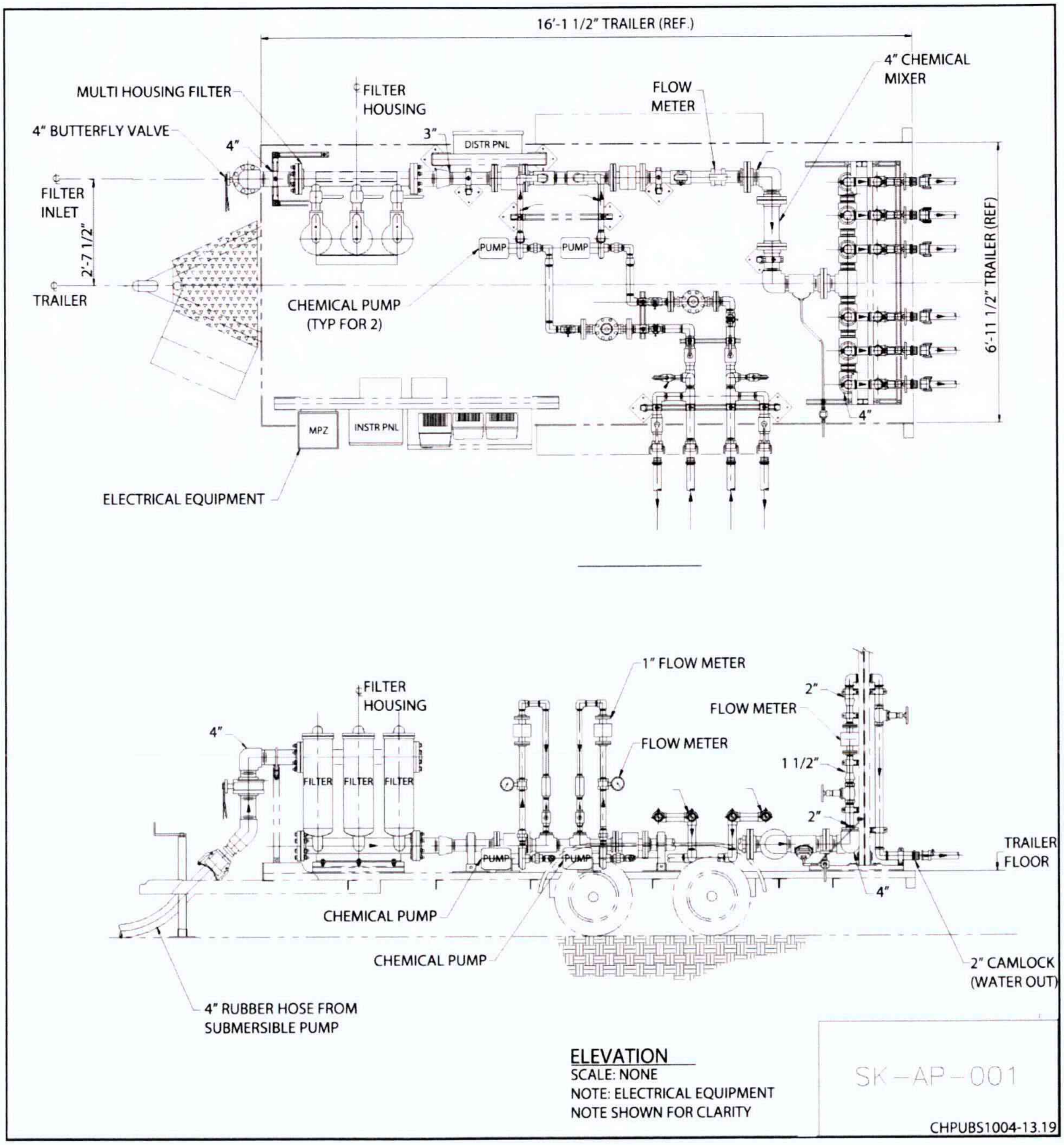


Figure 3-6. Generalized Schematic of Injection System

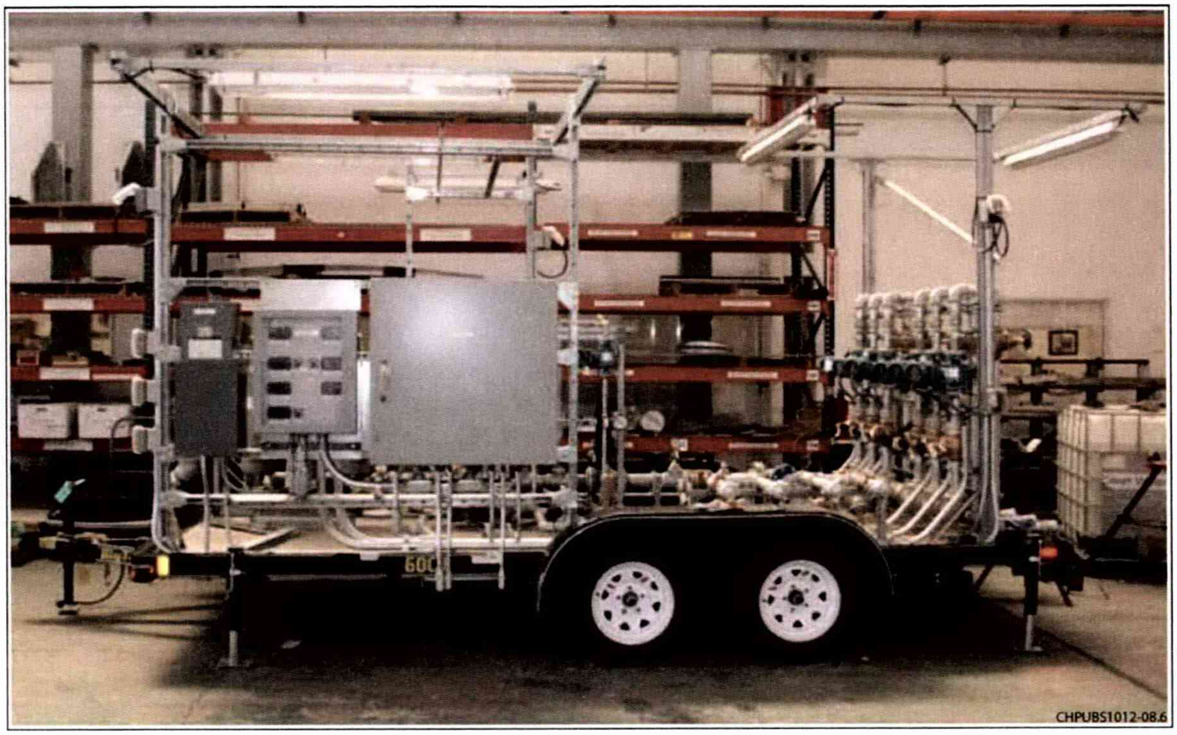


Figure 3-7. Photograph of Constructed Injection Skid

Each treatment skid is capable of pumping chemicals from tanker trucks or tanks and river water to form an injection solution for distribution to well heads. Flow meters and sample ports are provided on each injection skid to monitor and collect samples of premixed chemical solution. Submersible pumps in the Columbia River will extract and transfer river water to the injection skid, where it will be filtered prior to mixing with the chemical in a static in-line mixing chamber. Following mixing, a 5 cm (2 in.) transfer hose will distribute the dilute chemical solution to a manifold for distribution at up to six individual wells. A sample port is provided for sample collection of the dilute chemical prior to the manifold.

3.2.1.2 Monitoring, Sampling, and Analysis

Sampling and analysis requirements for the high concentration calcium-citrate-phosphate solution injections include chemical make-up sampling, injection flow rate and volume monitoring, groundwater and aquifer tube sampling, and some potential soil sampling after injections are complete.

Field instructions (*Field Test Instruction 100-NR-2 Operable Unit Design Optimization Study for Sequestration of Sr-90 Saturated Zone Apatite Permeable Reactive Barrier Extension* [SGW-47614]) have been prepared to guide the injections, and sampling requirements, and provide a detailed set of operational parameters and procedures.

Sampling will occur in a number of monitoring wells and aquifer tubes located within the potential area of injection influence along the 100-N shoreline before, during, and after treatment. SGW-47614 provides specifics on where soil cores will be collected, if determined necessary, which wells and aquifer tubes will be sampled, and the sample frequency, as summarized below.

Prior to injection, baseline sampling will be conducted from targeted multipurpose wells and monitoring wells. These samples will serve as the basis to compare the performance of the barrier. The sampling frequency will increase immediately following injection to identify potential short-term strontium-90 flux changes toward the river. Detailed sampling information is presented in SGW-47614.

During injection, flow rates and volumes will be monitored to test and optimize operation of the new injection skid and to verify that the system can deliver the designed injection solution flow volume at multiple well locations. Samples will be collected from the injection skid periodically to ensure that the apatite precursors are being injected at the correct concentrations.

Results from monitoring of groundwater and aquifer tubes will be used to evaluate progress with respect to the objectives described in Section 3.2.1.

Continuous core samples will be collected in conjunction with the DOS if the groundwater and aquifer tube monitoring data show a 90 percent reduction in strontium-90 flux to the river. If no considerable reduction is shown, re-injection will likely be implemented, and soil cores will not be collected. If deemed appropriate, core samples will be collected from locations to determine the vertical and radial extent of calcium-citrate-phosphate injection into the soil column and to determine the degree of apatite formation. A determination on the amount of strontium and strontium-90 incorporated in the apatite matrix, adsorbed to apatite material by ion exchange, and sorbed to sediments may be completed later. If conducted, continuous soil cores will be collected following the procedures outlined in DOS (DOE/RL-2010-29).

3.2.2 Vadose Zone Permeable Reactive Barrier

The existing 91 m (300 ft) long section of the PRB will be extended into the overlying vadose zone where a majority of the strontium-90 present along the river shoreline occurs. Vadose zone application will use direct (jet) injection methods to emplace pre-formed apatite. Design optimization of this remedy component will be conducted under DOE/RL-2010-68. The work described under DOE/RL-2010-68 will refine the jet injection method for emplacing apatite in the 100-N vadose zone.

Jet injection apatite emplacement will further immobilize strontium-90, thereby reducing, or eliminating transport from the vadose zone to groundwater and ultimately the Columbia River. The method for emplacing apatite in the vadose zone is described further in DOE/RL-2010-68. If successful, this test will result in vertical extension of the apatite PRB along its 760 m (2,500 ft) length.

The design optimization testing includes the following objectives:

- Achieve at least 3.4 mg apatite per gram of sediment emplacement in the vadose zone as a result of the jet injections.
  - This will be demonstrated through sediment core sampling as summarized in Section 3.2.2.2 and described in DOE/RL-2010-68 (Sections 7.3 and 7.4).
- Evaluate if apatite emplacement in the vadose zone can reduce reduction of strontium-90 release to the river during high water events.
  - The effectiveness will be demonstrated through groundwater and aquifer tube sampling as summarized in Section 3.2.2.2 and described in DOE/RL-2010-68 (Sections 7.3 and 7.4).
- Evaluate the ability of a combined saturated zone and vadose zone PRB to achieve up to a 90 percent reduction in strontium-90 flux to the river.
  - This will be demonstrated through groundwater and aquifer tube sampling as summarized in Section 3.2.2.2 and described in DOE/RL-2010-68 (Sections 7.3 and 7.4).
- Further, study the impact the phosphate jet injections in the vadose zone have on the release of strontium-90 and other metals from previously untreated sediments to groundwater and the river.

- This will be demonstrated through groundwater and aquifer tube sampling as summarized in Section 3.2.2.2 and described in DOE/RL-2010-68 (Sections 7.3 and 7.4).

The ability of the design optimization testing to meet these objectives will be established based on continued monitoring of groundwater and aquifer tubes and comparison to pre- and post-emplacement conditions in addition to sediment core samples. Since the vadose zone jet injections conducted under DOE/RL-2010-68 will take place directly above the existing 91 m (300 ft) long section of the saturated zone apatite PRB, post-injection monitoring will be reflective of the combined performance of the vadose and saturated zone PRB. Elevated metals and strontium-90 concentrations resulting from jet injection in the vadose zone may be mitigated as the injected water subsequently flows through the existing apatite PRB in the saturated zone. A minimum of three sediment core samples will be collected within a 3- to 12-month period following the jet injections to determine the concentration and distribution of apatite-forming phosphate and pre-formed apatite in the vadose and saturated zones.

3.2.2.1 Injection Design

Based on the favorable results observed during the initial pilot scale test, as presented in PNNL-19524 and SGW-47062, *Treatability Test Report for Field-Scale Apatite Jet Injection Demonstration for the 100NR2 Operable Unit*, vadose zone drilling will be performed using a phosphate solution, followed by jet injections of phosphate solution and/or pre-formed apatite. Prior to drilling and jet injections, a trench will be excavated. The trench size will be determined in the field to avoid existing injection/monitoring wells. Excavated soil will be used to create a berm around the trench to contain any material that may rise to the surface during drilling or injection. Once the injections are completed within a specific trench, it will be backfilled before moving on to the next trench. Other options for containing the drilling fluids may be considered, depending on the particular limitations of a given location.

Jet injection borings will be spaced in an offset pattern similar to that shown in Figure 3-8. Specific layout of jet injection borings will be defined prior to field implementation. All injection borings will be drilled using a hydraulic drill rig equipped with jet grout injection capabilities. The borings will be advanced from the bottom of the trench to TD using a rotary external wash drilling method. The target TD for each boring will extend to 4.6 to 6.1 m (15 to 20 ft) bgs; however, the actual TD of each boring will vary, depending on the geologic conditions encountered. Different drilling methods, such as water hammer, may be implemented as necessary.

The phosphate injection solution will be used as the boreholes are advanced. This will increase the amount of solution placed in the borehole and provide additional treatment further from the injection point. Residual rotary wash phosphate solution contained in the trench will also be allowed to infiltrate, providing for additional vadose zone treatment. An advantage of using jet injection to deliver materials is that the emplacement can be conducted independent of river stage, although water table elevation should be considered during the implementation of the injection plan.

Jet injections will be performed using a jet injection system capable of injecting the solutions at pressures up to 400 bars (5,800 psi). This high-pressure injection will mix (Figure 3-9) the soil with the injection slurry to a minimum radial distance of 1 m (3 ft) from the injection nozzle. The exact locations, number of injections, and the amount of phosphate and/or and pre-formed apatite will be stated in the jet injection field instructions.

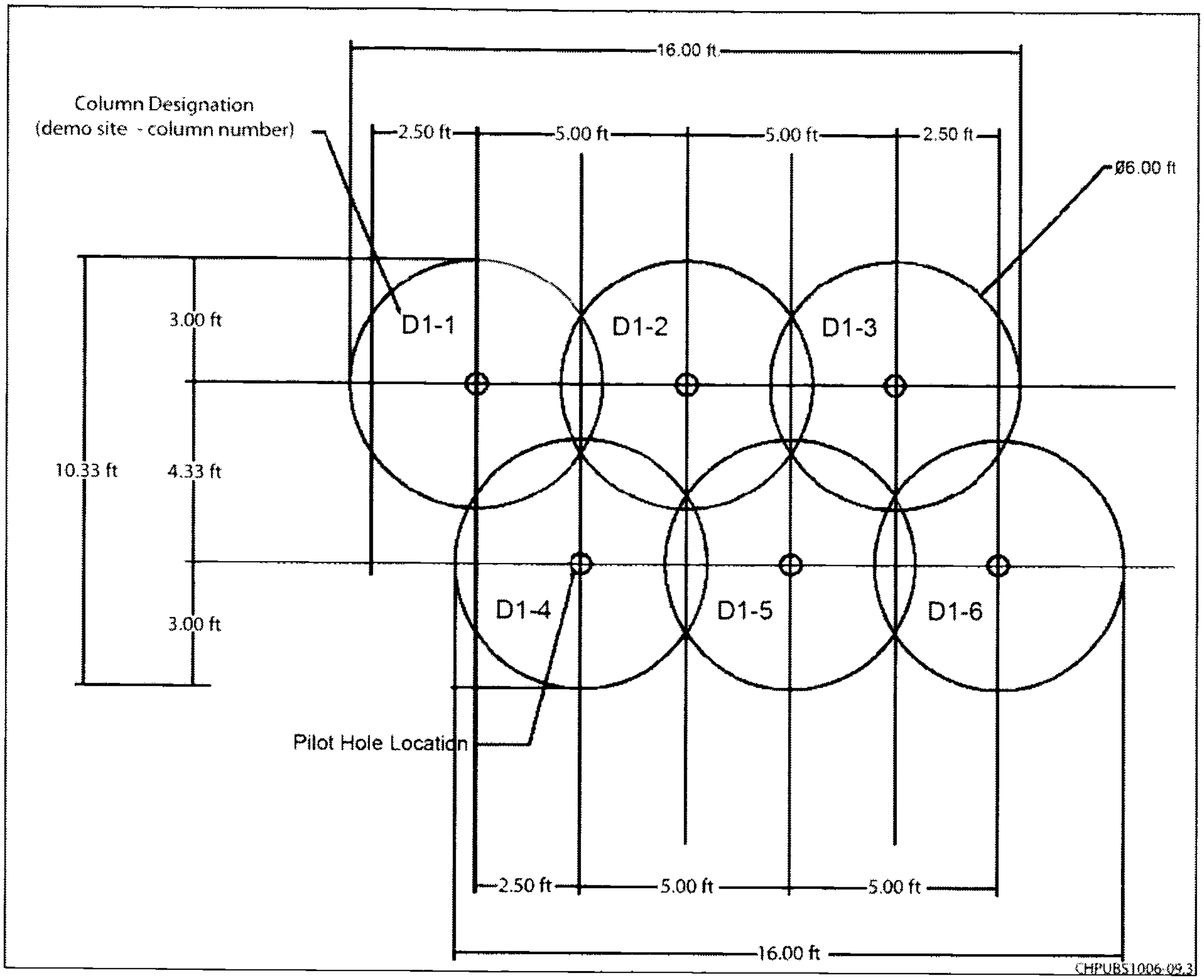


Figure 3-8. Example Jet Injection Layout

3.2.2.2 Monitoring, Sampling, and Analysis

Sampling and analysis requirements for the jet injections include chemical make-up sampling, injection flow rate and volume monitoring, groundwater and aquifer tube sampling, and sediment core sampling. Field test instructions will be prepared prior to the injections, which will include sampling requirements along with a detailed set of operational parameters and procedures. Sampling will occur in a number of monitoring wells and aquifer tubes along the 100-N shoreline before and after treatment. Specifics on where sediment cores will be collected, which wells and aquifer tubes will be sampled, and the sample frequency will be provided in activity specific field test instructions.

Prior to injection, baseline sampling will be conducted from select multipurpose wells, monitoring wells, and aquifer tubes. Where appropriate, data from other sampling events will be used. These samples will serve as the basis to compare the performance of the barrier. Sampling frequency will be initially increased immediately following injection to monitor any increase in strontium-90 flux toward the river. Sample frequency will decline over time. Specific sample location frequency and duration will be documented in the field test instructions.

During drilling and jet injection, flow rates will be monitored and any flow adjustments made, as necessary.

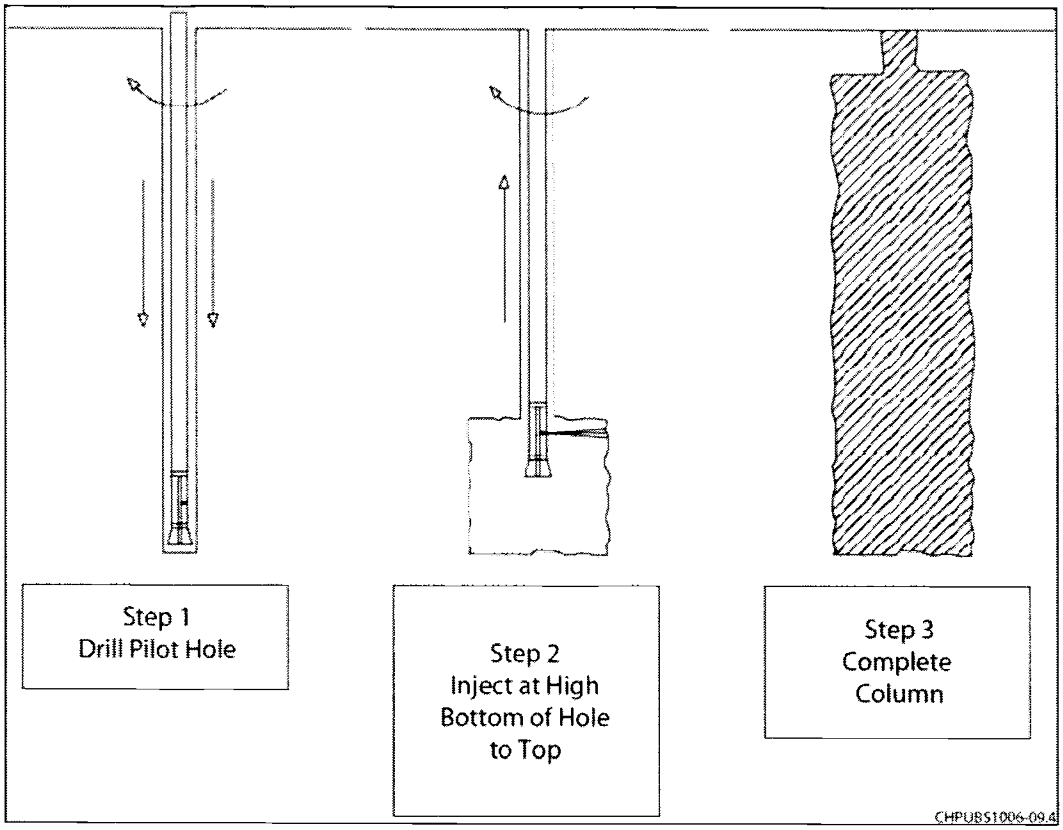


Figure 3-9. Typical Jet Injection Process

Results from monitoring of groundwater and aquifer tubes will be used to assess the effectiveness of the use of phosphate and/or preformed apatite in reducing the strontium-90 and other metals flux to the Columbia River, relative to baseline concentrations. Since all vadose zone jet injections conducted under DOE/RL-2010-68 will take place directly above the existing saturated zone PRB, post-injection monitoring will be reflective of the combined vadose and saturated zone PRB.

A minimum of three continuous core boreholes will be drilled through the vadose zone from within the PRB. Core samples will be collected for analysis at approximately 0.8 m (2.5 ft) intervals. Core samples will be collected at least three months, but not more than one year, after the jet injections at locations within the PRB and in alignment with existing downgradient monitoring wells to determine the nature and extent of the apatite-forming phosphate and/or preformed apatite emplacement. The cores will be collected from the ground surface to the top of the Ringold Formation upper mud. A determination on the amount of strontium and strontium-90 incorporated in the apatite matrix, adsorbed to apatite material by ion exchange, and sorbed to sediments may be completed later. Collection of continuous sediment cores will follow the procedures outlined in DOE/RL-2005-96, DOE/RL-2005-96-ADD3, and DOE/RL-2010-68.

3.2.3 Decommissioning Existing Pump-and-Treat System

The 100-NR-2 pump-and-treat system consists of injection wells, extraction wells, and associated vessels, pumps, and piping. The well network includes Injection Wells N-29 and N104A, Extraction Wells N-75, N-103, and N-106A, and backup Well N-105A. The system includes influent and effluent tanks and an IX skid with four columns.

To decommission the pump-and-treat system, all aboveground portions of the system, excluding the aboveground well components, will be removed, decontaminated, and disposed in accordance with ERDF waste acceptance criteria.

The wells will be left in place. The well completions (including surface seal, cap, and protective casing or monument) will be altered, if required, to comply with Washington rules for monitoring well construction.

3.2.4 Petroleum Hydrocarbon Contamination

The Interim Action ROD requires any free floating product observed in any 100-N wells to be remediated. Petroleum hydrocarbon contamination as free product has occasionally been observed at Wells 199-N-17 and 199-N-18. Well 199-N-17 went dry and was taken out of service and decommissioned. A passive removal method (Smart Sponge) was initiated in 2003 to remove the small amount of free product in Well 199-N-18. The approach was taken because the layer of floating petroleum was too thin for removal by active methods. The average mass removal rate in 2004 was 0.4 kg (0.9 lb) per month. Any additional wells with observed free product will be subject to this remediation approach.

If additional groundwater monitoring or remediation is required for the petroleum release sites, the change control procedures specified in Chapter 4 will be used to amend this document.

3.2.5 Groundwater Monitoring

As described in DOE/RL-2009-58, *100-N Area Integrated Groundwater Sampling and Analysis Plan*, groundwater monitoring activities in 100-N were proposed for unification under one program. All groundwater monitoring activities associated with implementing the provisions of the selected remedy described in this document will be performed as described in a revision to DOE/RL-2009-58.

3.2.6 Institutional Controls

ICs are required to prevent human exposure to contaminated groundwater present in the 100-NR-2 OU. Continued reliance on the existing institutional controls, as described in DOE/RL-2001-41, will meet the requirements of the Interim Action ROD Amendment. Existing ICs include access controls, water use and land use restrictions, and signs.

Access control is ensured through Hanford Site badging requirements and the use of signs posted along the Columbia River shoreline for restricted uses. Restrictions on certain land uses (e.g., restricting drilling or excavation) are administered through the onsite excavation permit process. DOE is responsible for establishing and maintaining land use and access restrictions until the 100-NR-2 interim action RAOs are achieved, or until a final remedy is selected and implemented.

DOE will prohibit activities that would interfere with interim action remedial activities. In addition, measures necessary to ensure the continuation of these restrictions will be taken in the event of any transfer or lease of the property. DOE will provide Ecology and EPA with written verification that these restrictions have been put in place.

Additional control measures for 100-NR-2 are included in DOE/RL-2001-41 (Tables A1-6, A1-8, and A1-10) pursuant to EPA/ROD/R10-99/112, *Interim Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units*; EPA/ROD/R-10-00/120, *Interim Remedial Action Record of Decision for the 100-NR-1 Operable Unit, Hanford Site, Benton County, Washington*; and EPA/ESD/R10-03/605, *Explanation of Significant Differences for the 100-NR-1 Operable Unit Treatment, Storage, and Disposal Interim Action Record of Decision and 100-NR-1/100-NR-2 Operable Units Interim Action Record of Decision, Hanford Site, Benton County, Washington*. These include the following:

- DOE will notify Ecology upon discovering any trespassing incident and will report the incident to the Benton County Sheriff's Office.
- Until final remedy selection, DOE will not delete or terminate any ICs requirement established in the Interim Action ROD unless Ecology has provided written concurrence and appropriate documentation has been placed in the AR.
- DOE will evaluate the implementation and effectiveness of ICs for the 100-NR-2 OU on an annual basis and report the result to the EPA and Ecology.
- Additional control measures are included in DOE/RL-2001-41, Table A1-9, for the 100 Area pursuant to the Interim Action ROD for the 100 Area Burial Grounds.

3.2.7 Riprap Cover

The boulder cover at the shoreline will be inspected every five years. Maintenance, which could include moving or adding riprap, will be conducted if needed.

3.3 Supplemental Design Tasks

No supplemental design related or treatability testing tasks beyond those described in this document are anticipated at this time. The injection system and multipurpose well network for the saturated zone PRB was designed and constructed as summarized in Section 3.2.1 and described in DOE/RL-2010-29. Emplacement of apatite in the vadose zone will be performed using commercially available, prefitted equipment, operated by a CHPRC subcontractor(s). Therefore, no additional design related activities are necessary.

3.4 Design Approach

The overall design approach for the saturated and vadose zone apatite PRB relies on the use of design optimization field studies to refine apatite emplacement methods and formulations, field test instructions to complete the apatite PRB build-out, and groundwater monitoring to assess progress with respect to RAOs. A majority of the infrastructure (multipurpose wells and injection equipment) has already been installed or fabricated as described in approved documents DOE/RL-2009-32, DOE/RL-2010-29, and DOE/RL-2010-68. The methods and sampling designs summarized in Section 3.2 represent the overall design and implementation approach that will be followed. Some variations from the described methods are anticipated. These changes will be handled as described further in Chapter 4. Detailed engineering drawings and specifications will not be prepared.

3.4.1 Remedial Design Report

A separate RDR for the amended interim action apatite PRB build-out is not planned. Following completion of the work described in DOE/RL-2010-29 and DOE/RL-2010-68, a final report(s) will be prepared summarizing the test results. Interim progress will be communicated through the Unit Manager Meetings and interim reports may be produced as determined by the project team.

3.4.2 Operations and Maintenance Plan

A separate O&M Plan for the amended interim RA apatite PRB build-out is not currently planned. However, an O&M Plan will be prepared once the apatite PRB build-out is complete and additional information on barrier maintenance and long-term performance monitoring requirements are identified. Following completion of the work described in DOE/RL-2010-29 and DOE/RL-2010-68, a final report(s) will be prepared summarizing the results of the testing. This report(s) will assess the need for long-term apatite PRB maintenance.

4 Remedial Action Management and Approach

This chapter describes the work elements and management approach associated with implementation of the selected remedy. The technical approach and management practices that will be used to meet the Interim Action ROD Amendment RAOs are outlined in this chapter.

4.1 Project Team

The project team includes all of the individuals working to accomplish the interim RA. Key project team members include DOE-RL (lead agency), Ecology (the lead regulatory agency), the 100 Area Lead, and the 100-N Project Manager.

Remedial Project Manager (DOE). DOE is the government agency responsible for RA throughout the Hanford Site and, as such, has assigned remedial project managers to each main area and task involved with remediation activities. A remedial project manager is responsible for managing the assigned activities, which include scope, budget, schedule, quality, personnel, communication, risk/safety, contracts, and regulatory interface.

Lead Regulatory Agency (Ecology). Ecology is the lead regulatory agency for the CERCLA remediation activities in 100-N, as described in the TPA. The lead regulatory agency is responsible for overseeing activities to verify that applicable regulatory requirements are met. Lead regulatory agency approval is required on all TPA primary documents (e.g., this RD/RAWP and the O&M Plan, if deemed necessary).

100 Area Lead (CHPRC). The 100 Area Lead provides oversight for all activities in the 100 Area and coordinates with DOE, Ecology, Washington Closure Hanford, and subcontractor representatives in support of remediation activities. The 100 Area Lead provides technical support to the 100-N Site Manager to ensure that all work is performed safely and cost effectively.

100-N Project Manager (CHPRC). The 100-N Project Manager is responsible for direct management of sampling documents and requirements, field activities, and subcontracted tasks. The project manager ensures that the field construction manager, environmental compliance officer, sampling coordinator, and others responsible for implementation of regulatory documents are provided with current copies of these documents and any revisions thereto. The Project Manager works closely with the Quality Assurance (QA) organization, the Health and Safety organization, and the field construction manager to integrate these and the other lead disciplines in planning and implementing the work scope. The project manager also coordinates with and reports to DOE, the regulators, and remediation and environmental managers on all remediation activities.

Environmental Manager (CHPRC). The environmental manager provides environmental oversight for document preparation as well as field activities. In addition, the environmental manager supports both the remediation manager and site project manager to ensure that work is performed in accordance with environmental requirements. The environmental manager coordinates with DOE and the regulatory agencies in support of remediation activities.

Field Engineering Lead (CHPRC). The field engineering lead provides technical guidance and direction of project and subcontracted work. The field engineering lead reviews plans, procedures, and technical documents to ensure that technical requirements have been addressed. The field engineering lead also identifies potential issues affecting operations, develops cost effective solutions, and oversees implementation of subcontractor tasks such as injection boring installation and apatite injection.

4.2 Change Management

The following three types of changes in the 100-NR-2 OU selected remedy could affect compliance with the requirements of the Interim Action ROD Amendment:

1. A **fundamental change** is a change that does not meet the requirements set forth in the Interim Action ROD Amendment or that incorporates remedial activities not defined in the scope of the ROD. Any fundamental change would be performed under a ROD amendment.
2. A **significant change** generally involves a change to a component of a remedy that does not fundamentally alter the overall cleanup approach. All significant changes will be addressed in an explanation of significant difference (ESD).
3. A **minor change** is a change that will not have a significant impact on the scope, performance, or cost of the remedy. Minor changes will be documented in the appropriate post-decision project file (for example, through interoffice memoranda or logbooks). Since these changes are not significant, they will not impact the requirements of the ROD or functional requirements.

Determining the significance of the change is the responsibility of DOE and Ecology. The 100-N Project Manager or Environmental Manager is responsible for tracking all changes and obtaining appropriate reviews. The Project Manager or Environmental Manager will discuss the change with DOE, and DOE will then discuss the type of change that is necessary with Ecology up to and including changes to Section 9.3 and Section 12.0 of the Action Plan. Appropriate documentation will follow, in accordance with the requirements for that type of change. Changes will not be implemented until DOE and Ecology concur on the change and the Interim Action ROD is amended or an ESD is issued, as appropriate.

The RCRA closure plans (contained in Appendices A and B of DOE/RL-96-39, *100-NR-1 Treatment, Storage, and Disposal Units Corrective Measures Study/Closure Plan*[DOE/RL-96-39]) will be modified through a permit modification (Class 1, 2, or 3 modification to the RCRA permit, "Permit Changes" [WAC 173-303-830]) whenever changes in closure activities or post-closure requirements arising from apatite PRB deployment occur. Any changes that differ from the language in the closure plan will likely require some level of RCRA permit modification. Prior to initiating the change, a review of the closure plans will be made, and the appropriate permit modifications will be requested and approved by Ecology. Examples of events that may require a RCRA permit modification include newly discovered dangerous waste constituents above action levels that require RA.

4.3 Remedial Action Work Tasks

Access to the apatite PRB deployment construction zone will be provided by the existing ramp and gravel access road that parallels the Columbia River. Construction activities will be limited by the width of the road bench, which in some areas is only 5 m (15 ft). It is assumed that no modifications are needed to permit truck and equipment access to the construction area. Injection equipment has been built to support the injections for aqueous emplacement of the additional lengths of the apatite barrier upstream and downstream of the existing barrier.

4.3.1 Procurement and Construction

Site utility requirements for deployment of the apatite PRB include a generator and water supply. A substantial amount of water is needed to make up the injection solutions. Columbia River water will be used to dilute the injection solutions (high-concentration calcium-citrate-phosphate and phosphate solutions) and to mix the preformed apatite slurry. A diesel generator will be used to operate the site facilities, injection/monitoring equipment, and ancillary equipment.

For the saturated zone injections, previous calcium-citrate-phosphate injections have been performed using injection skids to mix a dilute solution of river water and concentrated chemicals for injection. The previous injection skids had a limited capacity (injection limited to two wells at a time), which is considered insufficient to implement the initial and full-scale build-out. Two new injection skids were designed, constructed, and delivered to 100-N. The new injection skids increase the coverage area and decrease the time required for each injection. The new injection system design allows for injecting chemicals into six wells simultaneously. Prior to deployment, the systems will undergo acceptance testing including but not limited to leak testing, flow testing, and National Electric Code inspection.

For the vadose zone injections, jet injection nozzles capable of injecting the solution and/or preformed apatite at an injection pressure of approximately 400 bars (5,800 psi) will be used. Preblended phosphate mixture of food grade phosphoric acid and sodium hydroxide will be delivered in 18,927 L (5,000 gal) loads via tanker truck. The solution will be offloaded into holding tanks, with piping installed between the holding tanks and the jet injection pump. Preformed apatite will be delivered to 100-N and staged in a designated area.

4.3.2 Operational Approach

For the saturated zone injections, each treatment skid is capable of pumping chemicals from the tanker trucks (or the storage tanks placed on top of the bluff) and river water to form an injection solution for distribution to well heads. Flow meters and sample ports are provided on each injection skid to monitor and collect samples of premixed chemical solution. Submersible pumps in the Columbia River will extract and transfer river water to the injection skid, where it will be filtered prior to mixing with the chemical in a static inline mixing chamber. Following mixing, a 10 cm (4 in.) pipe will convey the dilute chemical solution to a manifold for distribution to up to six individual wells. A sample port is provided prior to the manifold for sample collection of the dilute chemical.

The volume of dilute chemical for injection will likely range from 94,625 to 454,200 L (25,000 to 120,000 gal) per well. The injection system is capable of injecting chemical solution at a flow rate from 37 to 189 L/min (10 to 50 gal/min) per well with a total capacity for each injection skid of up to 1,135 L/min (300 gal/min). Actual injection volumes will vary and will be determined and presented in the field test instructions.

Following completion of an injection cycle, the injection systems will be flushed with river water or raw water, and the water will be discarded to the ground within the apatite PRB footprint. The systems will be prepared for storage, then transported to and stored in a protected area, under cover, between injection cycles.

For the jet injections, a custom fabricated mixer equipped with multiple aggressive blades will be used to blend the preformed apatite product with water to form the apatite injection mixture. An auger will convey the apatite material into the mixing unit. The super sack storage unit will be equipped with load cells that can accurately weigh and deliver the proper proportion of apatite product to the mixer for each batch. Columbia River water will be delivered to the mixer through a flow meter that can deliver a consistent volume to each batch. A mission type pump will be used to recirculate and continuously agitate the apatite mixture.

A jet injection pump will be used to deliver the injection solution to the drill rig and jet grout tooling via a 4 cm (1.5 in.) diameter high-pressure hose. The apatite mixing unit and/or phosphate storage containers will deliver the injection solutions to the injection pump via flexible 7.6 or 10 cm (3 or 4 in.) hoses. The jet injections will use preformed apatite and/or phosphate solution. The injectable slurry of preformed apatite will be created onsite by mixing the selected solid apatite material with Columbia River water or potable water. Both the specific type of solid apatite material and the mixing ratio will be specified in the test instructions. The phosphate solution will be delivered premixed to the site. Specific required quantities of these materials will be addressed in the test instructions.

4.3.3 Project Status Reporting

Two different types of documents will be used to report the status of the project.

4.3.3.1 Progress Reports

Periodic progress will be communicated in the Unit Managers Meetings.

4.3.3.2 Remedy Performance Reports

Following completion of the design optimization studies described in DOE/RL-2010-29 and DOE/RL-2010-68, a final report(s) will be prepared summarizing the study results. Interim reports may be produced during implementation as determined by the project team. Interim action remedy performance will be summarized in future Hanford Site groundwater monitoring and performance reports. The information provided in future reports for the apatite PRB will be consistent with that provided in past reports.

5 Environmental Management and Controls

This chapter summarizes the environmental management controls associated with waste management, health and safety, emergency response, and the QA program.

5.1 Air Emissions

Radiological and nonradiological air emissions associated with deployment of the apatite PRB are not anticipated under the selected remedy.

5.1.1 Radiological Air Emissions

Radiological air emissions are not applicable to this interim RA.

5.1.2 Nonradiological Air Emissions

Nonradiological air emissions are not applicable to this interim RA.

5.2 Reporting Requirements for Nonroutine Releases

In 40 CFR 302, "Designation, Reportable Quantities, and Notification," immediate notification to the National Response Center is required on discovery of a release of a hazardous substance into the environment in excess of a reportable quantity. Any unplanned release of the apatite forming chemical sodium phosphate exceeding the reportable quantity of 2,270 kg (5,000 lb) will be reported. There is no reportable quantity for calcium-citrate.

In 40 CFR 355, "Emergency Planning and Notification," immediate notification to the community emergency coordinator is required for the local emergency planning committee and to the State Emergency Response Commission for a release of a reportable quantity of an extremely hazardous substance, a comprehensive release of a reportable quantity of an extremely hazardous substance, or a CERCLA hazardous substance. There are no extremely hazardous substances associated with emplacement of apatite-forming chemicals.

5.3 Waste Management

Waste management will be performed in accordance with a revision to DOE/RL-2000-41, *Interim Action Waste Management Plan for the 100-NR-2 Operable Unit*. The plan establishes the requirements for the management and disposal of waste associated with the interim actions, as stipulated in the Interim Action ROD. The plan also includes the requirements for the management and disposal of waste generated from activities such as groundwater monitoring.

Unused samples and associated laboratory waste for the analysis will be dispositioned in accordance with the laboratory contract and agreements for return to the project site. Pursuant to 40 CFR 300.440, "Procedures for Planning and Implementing Off-Site Response Actions," DOE-RL project manager approval is required before returning unused samples or waste from offsite laboratories (as applicable).

Table 5-1 presents a summary of projected waste streams expected during well drilling and development and apatite PRB deployment.

5.4 Cultural/Ecological Resources

Under DOE Order 451.1B, *National Environmental Policy Act Compliance Program*, Section 5.a.(13), DOE will "...incorporate NEPA values, such as analysis of cumulative, offsite, ecological, and socioeconomic impacts, to the extent practicable, in DOE documents prepared under the *Comprehensive*

Environmental Response, Compensation, and Liability Act." These *National Environmental Policy Act of 1969* (NEPA) values include, but are not limited to, cumulative, ecological, cultural, historical, and socioeconomic impacts, and irreversible and irretrievable commitments of resources. The vadose zone injections will occur in a previously disturbed area at 100-N, and do not have the potential to impact NEPA values. A general discussion of NEPA values anticipated to be addressed for the 100 Area can be found in DOE/RL-2008-46. The complete analysis will be provided in the future FS.

Table 5-1. General Waste Stream Description

General Waste Stream Description	Hazard Classification Anticipated	Container Options	Estimated Annual Volumes	Disposal Pathway Options	Hazard Source
Drill cuttings (dry soils and saturated slurries; sample returns)	Low-level, mixed, hazardous, dangerous, nonregulated	Roll-off boxes, drums	300 to 400 tons	ERDF	CERCLA
Liquids, but not limited to the following: decontamination liquids; purge water generated during well installation, development, testing, sampling and decant from drilling slurries, pore water generated from sampling of aquifer tubes, and unused and unmixed injection chemicals	Low-level, mixed, hazardous, dangerous, nonregulated	Purgewater trucks, temporary transfer drums	1,000,000 gal	Effluent Treatment Facility	CERCLA
Miscellaneous solid waste, but not limited to the following: personal protective equipment, cloth, plastic, wipes, wood, equipment, tools, pumps, wire, metal casing, plastic piping, sample returns, etc.	Low-level, mixed, hazardous, dangerous, nonregulated	Burial box	2 tons	ERDF	CERCLA
Excess pre-mixed chemicals/ reagents	Nonregulated	Unused reagent chemicals that have been premixed will be infiltrated within the apatite PRB footprint to promote additional vadose zone treatment			Nonregulated
Decontamination and Demolition debris (from pump-and-treat decommissioning) such as, but not limited to, concrete, wood, rebar, metal/plastic pipes and screens, wire, bentonite, sand, gravel, equipment, pumps, and tanks	Low-level, mixed, hazardous, dangerous, nonregulated	Burial boxes	10 tons	ERDF	CERCLA, nonregulated

Based on the NEPA evaluation presented in the Proposed Plan, the long-term environmental impact of the apatite PRB will be positive, substantially mitigating strontium-90 contamination in the environment. Short-term impacts during the interim RA will be mitigated to stay within standards established under the identified ARARs. The long-term positive environmental impact of remediation clearly outweighs the short-term, limited impacts during remedial construction activities.

Since the area associated with the apatite barrier installation has been previously disturbed, this project is not expected to cause effects to historic properties, per 36 CFR 800, Subpart B, and no further actions would be required. This assumption will be evaluated and confirmed as part of the DOE Hanford Cultural Resource Program (HCRP) cultural release process prior to initiation of field activities. Additionally, as a precaution, all workers will be directed to watch for cultural materials (e.g., bones and artifacts) during all work activities. If any are encountered, work in the vicinity of the discovery must stop until a DOE HCRP archaeologist has been notified, assessed the significance of the find, and arranged for mitigation of the impacts to the find, if necessary.

5.5 Health and Safety Program

All field operations will be performed in accordance with CHPRC health and safety requirements, outlined in the latest revision of the Soil and Groundwater health and safety plan. Radiological contamination is probable during performance of injection boring drilling and sampling activities. The sampling processes and associated activities will take into consideration exposure reduction and contamination control techniques (e.g., as low as reasonably achievable [ALARA] and Integrated Safety Management System) that will minimize chemical exposure to the sampling team. Health and safety personnel will use data collected during the activities addressed in DOE/RL-2010-29 and DOE/RL-2010-68 as input to determine exposure levels to workers, and to conduct health and safety assessments during all field activities.

All hazard controls associated with the apatite injection will be controlled by job hazard analysis process implemented through DOE-approved programs and contractor-approved internal work requirements and processes.

The health and safety officer is responsible for coordinating industrial safety and health support for the project and other pertinent safety documents required by federal regulation or by internal primary contractor work requirements. In addition, the CHPRC health and safety program assists project personnel in complying with applicable health and safety standards and requirements, and coordinating with radiological engineering to determine personal protective clothing requirements as necessary.

5.6 Quality Assurance Program

The QA Engineer is responsible for QA issues on the project. Responsibilities include, as appropriate, overseeing implementation of the project QA requirements; reviewing project documents, including data needs summary reports, field sampling plans, and the quality assurance project plan; and participating in QA assessments of sample collection and analysis activities. The QA point of contact must be independent of the unit generating the data.

QA and quality control procedures have been developed for the saturated and vadose zone 100-NR-2 Groundwater OU apatite PRB build-out. Methods for sampling and analysis, data management, and data interpretation are presented in DOE/RL-2010-29 and DOE/RL-2010-68.

6 Remedial Action Completion

This chapter describes how the effectiveness of the apatite PRB interim RA component will be evaluated and the contingency actions that may be implemented if the 90 percent strontium-90 flux reduction goal is not achieved. The compliance monitoring strategy that will be used to show attainment of the 8 pCi/L RAG in the hyporheic zone will be presented in the RD/RAWP for the final remedy.

6.1 Remedial Action Exit Strategy

The apatite PRB will likely be an important component of the final remedy for 100-N, which will be implemented following issuance of a final ROD. At this time, there is no exit strategy for this interim RA other than to include it as a component of the final remedy if supported by the CERCLA evaluation to be presented in the final RI/FS Report.

Achievement of the 90 percent flux reduction goal will be determined by comparing strontium-90 concentrations in groundwater samples collected downgradient of the apatite PRB against the concentrations observed at the same well during the baseline or pre-injection sampling event. Percent concentration reductions at individual wells will then be averaged along the apatite PRB's full length to determine the overall percent concentration or flux reduction. Time series charts will be prepared for individual wells and the percent reduction will be calculated at the end of the five-year monitoring period. An example of the concentration reduction calculation is provided in Table 6-1.

Table 6-1. Example Calculation of Strontium-90 Concentration Reduction Calculation

Well Name	Sample Date Range	Strontium-90 Concentration (pCi/L)			Percent Reduction in Strontium-90 Concentration[a, b]		
		Minimum Baseline	Maximum Baseline	Last Observed Post-Treatment	Minimum Baseline (Percent)	Maximum Baseline (Percent)	Average Baseline (Percent)
199-N-122	8/13-20/10	657	4630	100	84.8	97.8	91.3
199-N-123	8/13-20/09	689	1180	70.0	89.8	94.1	92.0
199-N-146	8/13-20/09	318	985	85.0	73.3	91.4	82.4
199-N-147	8/13-20/09	522	1842	65.0	87.5	96.5	92.0
						Average Across Apatite PRB	89.4

a. This information is provided as an illustration only and does not represent the current or projected performance of the apatite PRB at any location.

b. Percent reduction = ([Baseline (Min or Max) – Last Observed Post Treatment] ÷ Baseline [Min or Max]) * 100.

6.2 Contingency Action Plan

An additional round of apatite injections, at a subset of injection well locations, may be performed within five years of completing all first-round apatite injections to support achievement of the 90 percent reduction in strontium-90 flux to the river. If the strontium-90 flux reduction is not achieved following the additional injections, and implementation of any final actions is deemed necessary in the final ROD, and an additional response is deemed necessary after the five-year period, the Tri-Parties will propose alternative actions to be taken. Conditions that will be used to determine the need for additional injections will be assessed by the Tri-Parties as the performance monitoring data become available.

6.3 Interim Remedial Action Completion Report

DOE and the regulatory agency project managers will determine the need for a final inspection based on the results of the prefinal inspection and the content of prefinal inspection report. A final inspection will verify the closure of open items from the prefinal inspections and will confirm and document that satisfactory progress toward achievement of the flux reduction goal is being made. The final inspection, conducted by the Tri-Parties project managers, will confirm the resolution of outstanding items identified in the prefinal inspection and verify that the remediation has been completed in accordance with the requirements of the Interim Action ROD Amendment. The results of the final inspection will be incorporated in the site's completion report. Information collected as part of the final inspection and final inspection report will be no less than that collected during a prefinal inspection and prefinal inspection report. The final inspection report should contain the following elements:

- Results of the final inspection
- Evaluation of the effectiveness in meeting treatment system performance requirements based on the results of the shakedown period

Following full build-out of the apatite PRB, DOE will prepare an interim RA completion report. The report for a given OU is used only for RAs that include groundwater or surface water restoration remedies, including MNA. Interim reports are used because of the long delay between construction of the remedy and achievement of cleanup goals.

7 Cost and Schedule

This chapter provides the project schedule broken down into major phases or components. The schedule will reflect completed milestones to date and enough detail to allow development of future milestones. Document review protocol and requirements will be incorporated into the schedule and, if developed, schedules for performing activities will be provided subsequent to or in coordination with this project.

7.1 Cost Summary

A cost estimate for the apatite PRB for the FY 2012 to FY 2016 time frame is provided in Table 7-1, and a schedule for the build-out and footage to be added each year is provided in Figure 7-1. Upfront planning and design, system construction, startup, and initial operations are included.

The cost estimate presented in this section is based on the best available information regarding the anticipated scope of the apatite PRB build-out. The cost estimate represents an order of magnitude estimate with an expected accuracy of + 50 to -30 percent. Changes in the scope of the apatite PRB design and its construction may arise as a result of new information obtained through implementation of the work described in DOE/RL-2010-29 and DOE/RL-2010-68. These changes will likely result in a final project cost that differs from the estimate presented herein.

Table 7-1. 100-NR-2 Amended Interim Action Apatite PRB Cost Estimate (2012 to 2016)

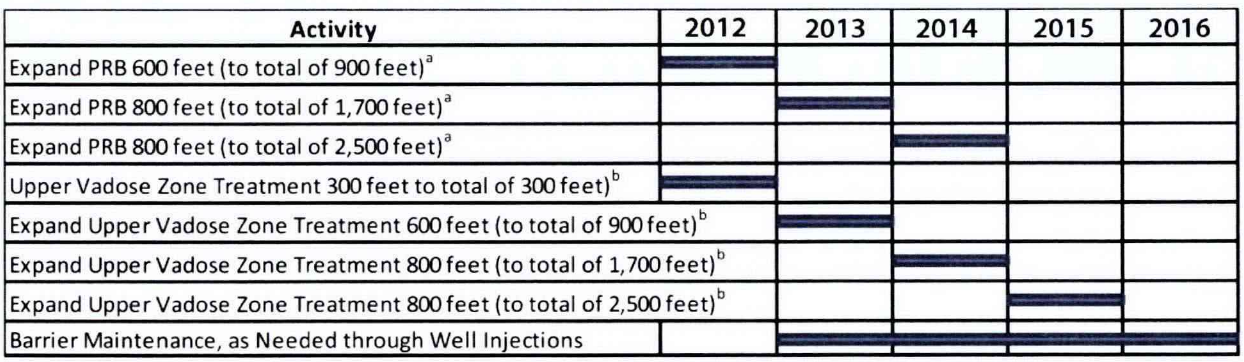
FY	Activity		Estimated Cost
2012	Barrier Maintenance		$312,300
	Barrier Expansion Sampling Support		$148,300
	Barrier Expansion Injection Support		$2,067,700
	Barrier Expansion Injection Skid Maintenance		$50,900
	Upper Vadose Zone Barrier Expansion		$1,651,300
		Subtotal	**$4,230,500**
2013	Barrier Expansion Sampling Support		$151,200
	Barrier Expansion Injection Support		$2,025,200
	Upper Vadose Zone Barrier Expansion		$3,363,700
	Barrier Expansion Quarterly Monitoring		$359,200
		Subtotal	**$5,899,300**
2014	Barrier Expansion Sampling Support		$37,800
	Barrier Expansion Injection Support		$506,300
	Upper Vadose Zone Barrier Expansion		$819,600
	Final Barrier Expansion Support		$37,800
	Final Barrier Injection Support		$168,800
		Subtotal	**$1,570,300**

Table 7-1. 100-NR-2 Amended Interim Action Apatite PRB Cost Estimate (2012 to 2016)

FY	Activity		Estimated Cost
2015	Barrier Expansion Sampling Support		$146,400
	Barrier Expansion Injection Support		$505,100
	Upper Vadose Zone Barrier Expansion		$2,456,100
		Subtotal	**$3,107,600**
2016	Barrier Expansion Sampling Support		$146,400
	Barrier Expansion Injection Support		$505,100
	Upper Vadose Zone Barrier Expansion		$2,456,100
		Subtotal	**$3,107,600**
		Total Estimated Costs (2012 to 2016)	**$17,915,300**

7.2 Schedule

Figure 7-1 provides a projected schedule through full build-out of the apatite PRB.



[a] PRB expansion under this RD-RAWP is described in approved Design Optimization Study (DOE-RL, 2010)

[b] Vadose zone treatment under this RD/RAWP Rev. 1 is described in DOE/RL-2010-68.

CHPUBS1103-07.01

Figure 7-1. Remedial Design/Remedial Action Work Plan (Rev. 1) Schedule

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